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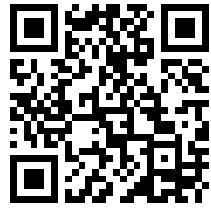

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THE JOURNAL
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MARYLAND ACADEMY OF SCIENCES

Volume I

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THE MONOPHONE*

GEORGE O. SQUIER, K.C.M.G., D.S.M., PH.D., D.Sc.

Major General, United States Army, Retired

The Monophone is an extension of wired radio as now used in the Bell system, to deliver with a degree of perfection not heretofore attained super-programs into the home from the distributing telephone switchboards. If it had been invented and developed some years ago, the whole history of broadcasting in the United States would have been different and the present confused state of the art would not have obtained.

Space-radio has already reached the "saturation point" in its assigned band of frequencies. The new fields for the use of this art, developing almost daily, show a fertility, the limits of which no man may rightly set bounds about or properly meter.

Therefore, it is proposed through the agency of the Monophone to put the telephone wires now leading into millions of homes, to work sixteen hours a day in providing multiple program service. The Monophone must and does accomplish this without interfering with the regular point-to-point telephone service or changing its present equipment in any way.

MONOPHONE THEORY

The principle of the Monophone invention is at once in marked contrast and supplementary to the original invention of multiplex telephony. In 1910 I brought to the telephone art the new art of wireless, superimposing so to speak, the latter upon the first.

Instead of erecting an antenna as Marconi originally did, I applied the apparatus, methods and principles of wireless to a standard twisted cable pair, which instead of radiating energy in all directions, guided it effectively to the distant receiving point. In 1926, or sixteen years later, when I invented the Monophone, I again started with the "twisted-pair," but went directly back to

* Received for publication December 19, 1929.

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original plans and set up a complete space-radio system inside a cable and buried under ground. Instead of broadcasting from an antenna through great stretches of space, the problem was simplified by radiating programs to hundreds of homes through subterranean antennae comprised in a single cable equipment and through distances measured by the thickness of the paper used for insulation. But it turns out by experiment that the Monophone subterranean radio plant is so efficient that it takes but a few watts instead of kilowatts to distribute to a whole city a symphony concert.

The reason for this is that for some years municipal authorities in the first instance, and communication engineers in the second have been getting ready for the advent of this new type of one way service, both for broadcasting and television, by covering the telephone cables with a lead sheath which screens the whole system, both transmitting and receiving antennae, from end to end, including, if desired, the studio room and the receiving apparatus into a world of zero noise-level.

From the technical point of view, the beauty and elegance of the Monophone invention is its simplicity. A patent was applied for in the United States on July 17, 1926. After a long-drawn prosecution in which an interference was declared involving some seven foreign and domestic inventors, the matter has been settled in my favor and the patent will issue shortly.

One does not have to be qualified either as an engineer or as an attorney to understand the count involved in this interference, which reads as follows:

"In a system for introducing signals into telephone subscriber's station, the combination with a telephone cable comprising a plurality of subscribers' loops, of an antenna within the cable comprising one of said loops, means for delivering high frequency energy to said loop whereby the energy is communicated to all the other loops in the cable, and means for receiving energy from each of the said subscribers' loops at his station."

This claim is pronounced by War Department patent experts to be one of the broadest and most comprehensive ever allowed by the United States Patent Office.

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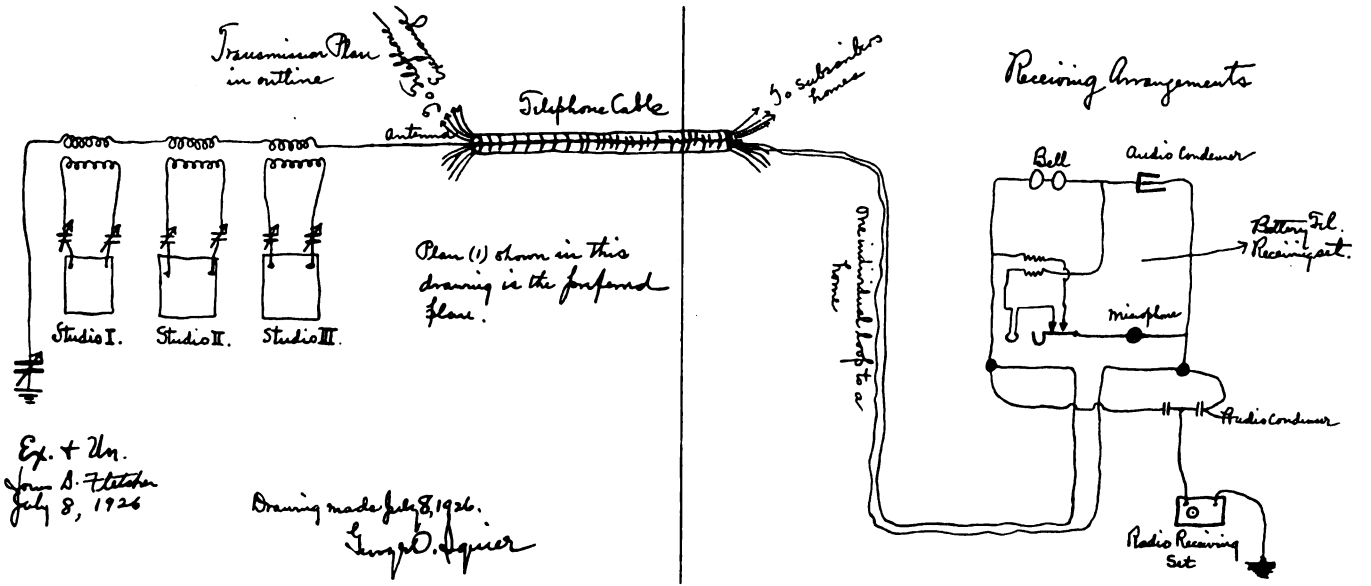

INDIVIDUAL HOMES SERVED BY THIS CABLE, WHERE THEY ARE INTERPRETED BY THE RADIO RECEIVING INSTRUMENTS INSTALLED THEREIN

One general plan of wiring is shown in the drawing facsimile of original drawing of monophone circuit made at 3 a.m. at Hotel Astor, New York City, July 8, 1926.

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Owen D. Young and General Harbord did a great public service in financing the National Broadcasting Company to get the new industry started, but they are now pushing the "free principle" too far. The reaction has set in and urban people are demanding the privilege of paying for their radio free from advertising, as they now pay for their electric light and telephone service. In the super-university of the United States conducted by radio for both youth and adults side by side in the home, which is already started by the President, the American people will not turn this great educational adventure over to the chances of commercial advertising of commodities.

Space radio is entirely unsuited to these days of congested steel skyscrapers in our cities, and it must be reserved for the long-haul in the open country, for aviation and for ships at sea.

Many years ago both the telephone wires and the electric light wires were ordered underground by city authorities because they offended the eye and interfered with traffic in the streets. In like manner within a short time, unless voluntarily accomplished, space-radio will be also ordered underground and carried by these same wires, because it offends the ear instead of the eye and interferes with radio traffic. In New York City we put even the people themselves underground into huge conduits to avoid congestion.

The Monophone employs a band of frequencies never before used either in space radio or in the so-called "carrier art" as developed in the Bell system. This band is also entirely above and out of the way of the band used by wired radio on power lines for broadcasting service.

SELECTING A NAME

Just as I found much difficulty nineteen years ago in selecting a name for "multiplex telephony by means of electric waves guided by wires" and finally settled on the popular name at that time of "wired-wireless," so three years ago I spent several months in searching for a name for this new type of telephone service. It was realized in the first place that when Professor Bell fifty years ago said, "Mr. Watson, please come here. I want you," he was

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using a one-way telephone and nothing more. It seems not unreasonable to suppose that what we now call broadcasting might have been born then and there.

He had already invented the "soft-speaker" or "telephone-voice." All that was needed was a "loud-speaker," to fill the room with a program. If the need had been realized, history shows that an answer would have been found. The word "monophone" is more beautiful than the word "telephone," and being derived from the Greek, it easily becomes international in character. In German it is Monophon, in Spanish, Monofono, in Italian, Monofono, and in French and English, Monophone.

OUR MACHINE AGE

Mr. Owen D. Young, in an address delivered recently when receiving an academic degree, called the research men "the poets of today," who may "make the machine age immortal."

When the engineer delivers Galli Curci's voice, or a Beethoven concert, or Lincoln's Gettysburg Address a thousand miles over wires or through space and into the family circle, and then measures its cost by merely observing a "pointer reading" on the dial of a wattmeter, he lifts his profession to an exalted position in the spiritual world.

The amazing powers with which the individual human being of the present age has been endowed by the inventive progress of the past half-century have often been dwelt upon, yet they are perhaps not universally realized. Let me cite one example.

Consider the vast telephone system of the United States; the most elaborate and complicated array of electrical network organized for a particular national function ever conceived by the mind of man. Telephony is both a science and an art, and more than these. Some nineteen million telephones in this country are interconnected by enough wire to reach more than half the distance from the earth to the sun, over which sixty million separate conversations are carried on each day. The suspension of this service for a single hour would throw the entire mechanism of modern American life into utter confusion. Nor is this system limited to our own people. Recently through a transoceanic

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ethereal link, the countries of Europe have been one by one joined together with us as neighbors into one grand "planetary" chain.

In this country alone, over three hundred thousand trained employees, physicists, engineers, executives, financiers, operators and technicians of all sorts are constantly working in coördination to achieve a result which would have seemed utterly impossible fifty years ago.

This vast army of employees is organized into army corps, divisions, brigades, regiments and companies, for rigid discipline and divided responsibility under the same general principles as those of an army in the field. Nor is there lacking a general staff in the form of a board of directors to determine the grand strategy of its operations. The commander-in-chief, the president of the company, with responsibilities comparable with those of our postmaster general, could with propriety demand the oath of office by the chief justice. For this army there is no peace; the battle is on every moment indefinitely with no chance for an armistice.

The young man or woman now entering upon his lifework in this new era inherits a power without any effort on his part which no one can measure. For instance, when he takes down a telephone receiver and calls the nearest central station he is put in command, for the moment, of this vast army of three hundred thousand men, and whatever his orders, even to the most remote private soldier on the most distant frontier, they are promptly obeyed.

The vast wire pattern ever changing from instant to instant, to bring about this national conversation, baffles the imagination and may be likened to some gigantic musical instrument or stringed lyre played upon by millions of our citizens every day.

This wire pattern knows no law, no mathematical theory of probability can predict its infinite combinations, permutations, and arrangements which never repeat themselves as time goes on. They silently carry our joys, our griefs and the nation's business and, if perchance we were suddenly endowed with some new type of color television, which would enable us to visualize this colossal scene, as the myriad messages pass to and fro—what

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a spectacle to behold! A chameleon-like tapestry on a continental scale. If we could suddenly "radioize" this system of national telephone conversations by hitching to it a gigantic power-driven loud-speaker, what a Babel roar would ascend to heaven!

Who then shall say that this age does not rival the golden Age of Pericles? The telephone system of today is a business but it is also as spiritual and artistic, in its own new way, as the design of St. Peter's, the painting of the Sistine Madonna, or the composition of a Beethoven Sonata.

The organization, equipment and training of this vast mechanized army has required a full half-century. The terrain has extended to include our whole land. Great indeed has been the victory, but there are amazing years ahead.[1] Education, culture and amusement in the home now make an irresistable appeal to our new-found leisure and prosperity. If the commander-in-chief and the general staff will assume full control of this army and issue the necessary orders to the engineer corps, the junior officers and privates will soon attain a new uplifting agency as an integral part of the American home.

[1] "The Amazing Years Ahead," by Major General Squier. *Nation's Business*, January, 1929.

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SOARING FLIGHT*

A. F. ZAHM, PH.D.

Director, Navy Aerodynamical Laboratory†

In sunny weather one not infrequently may observe a hawk or vulture drift with the wind across country while continually wheeling round and round on expanded rigid wings, maintaining or gaining altitude with no apparent effort. Such passive flight, in fact all passive flight without loss of energy, is called soaring; dynamic if effected in a purely horizontal wind, up-current if the air has a material rising trend.

PRINCIPLES OF DYNAMIC SOARING

The early writers on aviation assumed the wind to blow horizontally with varying velocity which certain expert birds could employ for sustentation and propulsion. When the wind was accelerating they would face it to acquire lift and increased speed, possibly even greater speed than the wind, which could result from combining their initial speed and the wind speed in a cross-wind glide on a semi-ellipse bowing upstream. When the wind slackened, their enhanced velocity and elevation would enable them to glide over a like semi-ellipse bowing downwind, without loss of their original altitude. Having thus made a complete circuitous glide in the period of one gust, they would now face the next puff and begin a new cycle; and so on indefinitely.

Some writers even offered observations and theory to show that soaring can be achieved in a uniform horizontal wind. But here Lord Rayleigh intervening, with his usual conciseness and lucidity, showed that such a wind is equivalent to a calm.[1] "I presume that if we know anything about mechanics, it is certain

* Received for publication December 16, 1929.

† Since December, 1929, Chief, Division of Aeronautics, Library of Congress.

[1] *Nature*, April 5, 1883. Also *Manchester Memoirs*, Vol. XLIV (1899), No. 5., "Mechanical Principles of Flight."

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that a bird, without working his wings, cannot, either in still air or in a horizontal wind, maintain his level indefinitely. For a short time such maintenance is possible at the expense of an initial velocity, but this must soon be exhausted. Whenever, therefore, a bird pursues his course for some time without working his wings, we must conclude, either (1) that the course is not horizontal, (2) that the wind is not horizontal, or (3) that the wind is not uniform."

Early in 1893 Professor Langley and the present writer independently made instrumental records of wind velocities, he with a light cup anemometer above the Smithsonian main tower, I with a recording anemograph in a 200-acre level tract just south of Notre Dame University; and both to obtain data to elucidate sustained passive flight. Reports of these records were published with the *Proceedings of the International Conference on Aerial Navigation*, held during the World's Fair in 1893.[2] Sample records are shown in figures 1, 2; also a recent British record in figure 3.

From his measurements Langely inferred that, quite generally over the earth, the fluctuations of the wind's horizontal speed are sufficient to enable a man to "circumnavigate the globe without alighting," in an "aerodrome" with reserve engine power "to take care of itself in exceptional moments or calm." From the same records, however, I inferred that soaring might be aided by such pulsations, but could not long be sustained, except by a bird or glider more efficient than any known in 1911, when I discussed the records.[3]

In that discussion I assumed the lift to drag ratio as 8 to 1, about the best available then. More efficient gliders have been developed since, especially by the Germans in their soaring contests. Dr. Klemperer reports the achievement of a 20 to 1 lift to drag ratio, in a refined glider construction.[4] Recently a well known writer on aerodynamics maintained that certain birds

[2] Langley, "Internal Work of the Wind;" Zahm, "Atmospheric Gusts and Their Relation to Flight."

[3] Zahm, "The Undeveloped Art of Soaring," *Sc. Am. Sup.*, November 18, 1911.

[4] "Soaring Flight," *Jour. Franklin Inst.*, September, 1927.

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can glide 200 feet in a descent of 1 foot through still air, and that an airplane model of like efficiency can be made. But when I offered to wager that he could not attain one-fourth of that efficiency he found business reasons for declining the wager. The

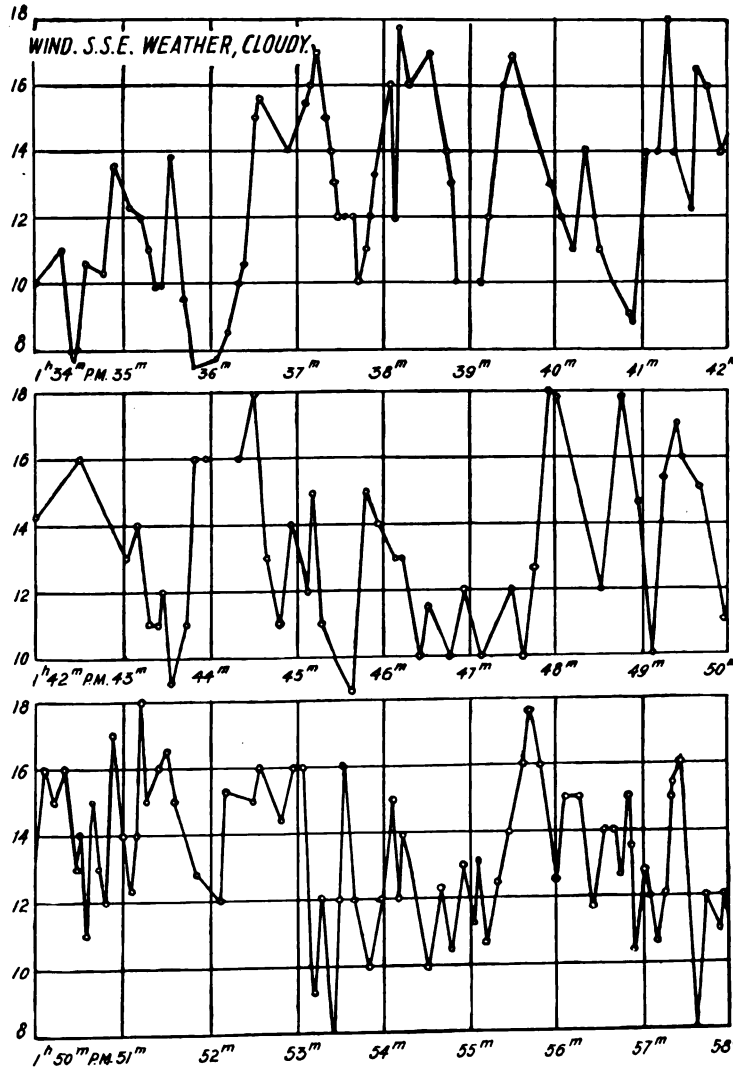

FIG. 1. RECORDS OF WIND SPEED OBTAINED BY LANGLEY, 1893
Ordinates-wind speed in mile per hour

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best figure for a simple wing of 6 to 1 aspect ratio is now about 30 to 1.

Assuming a craft capable of a 20 to 1 glide, we may admit the possibility of its continuous soaring in air whose horizontal acceleration, constantly met in a favorable direction, averages something over 20/32 feet per second, say 2 feet per second. But where can such winds be found? Figure 1 shows some such acceleration during the second minute interval, but in the third and fourth together not half that required.

It seems improbable that there is any material amount of dynamic soaring, or prolonged flight without loss of altitude in level winds, to be expected in art or nature. To begin with, anemograph records show variations of wind direction simultaneously in both horizontal and vertical planes. Furthermore, purely horizontal winds cannot occur near ordinary obstacles, such as ships, waves, abrupt beaches, bluffs, trees, etc.; nor along or across flat valleys tapered or hedged by nearby hills; nor over smooth level plains heated by the sun; for all such conditions entail vertical components in any air airstreams that initially might be level. The most promising place to look for true horizontal airflow is well above the highest mountain peaks and clouds; say above the isothermal layer, or high over vast bodies of water free of storm or large obstruction or strong sunshine. But in such places sustained passive flight does not occur. Even over a favorable flat terrene, where ordinarily there is much soaring of the great scavengers, one may see, on a day of prolonged dark sky, some plodding vulture—if indeed one venture forth—beat his wings almost continuously to escape gradual loss of elevation. The level wind void of sun-begot upflow lacks efficacy.

Still it is theoretically possible to achieve passive flight in a horizontal wind whose speed varies rapidly at neighboring levels or in different striae at the same level. The bird acquires in the swifter stratum speed sufficient to glide into the slower one, there reverse and return against the swifter current, to be caught up and given a downwind speed as before. Many such performances have been attested, but without instrumental proof of the assumed air flow.

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The theory has been presented by Lord Rayleigh in his "Mechanical Principles of Flight," by Voght in *London Engineering*, and by various other writers. The fact that the wind has materially different speeds in different strata and striae is well attested; but quantitatively can one prove that the rate of change of speed is quite commonly sufficient to support prolonged soaring?

In a horizontal wind that pulsates only from side to side, the bird may derive aid by the alternate aerial impulses resisted by its inertia. If the wind freshens from the right quarter and the flier lists to port, he is driven to port; then if it blows promptly from the left quarter, while the flier tilts to starboard, he has his acquired component of momentum to port reversed, and therefore drifts to the right. In such case the resultant force on the wings may have a forward component tending to overcome the head resistance. Continuous soaring in such a laterally pulsating air stream would, however, require very rapid and wide fluctuations of wind direction, and great alertness in the flier.

PRINCIPLES OF UP-CURRENT SOARING

Of winds having an upward trend we may notice (1) undulatory currents, (2) stationary deflected currents, (3) convection currents. Each of these may be strong enough to sustain continuous soaring.

The vertical undulations shown in figure 2 seem hardly adequate to support passive flight, though they might assist if adroitly used. More familiar and effective are the regular aerial billows caused by one stratum of air blowing over another of sharply different density, or over a broad expanse of water having depth enough for high wave formation. Various sea birds, notably the albatross with his outdrawn slender wings, glide indefinitely with ease along the great beach combers and over the ponderous curlers of mid-ocean. They have only to ride the ascending air to increase their momentum. With the energy so acquired from the heaving surface of the sea the competent air sailor floats from billow to billow far as ship can navigate, and sometimes possibly sleeps on the wing, as sailors have reported.

Akin to this performance is the soaring of sea gulls in certain

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favorable localities at the side of a ship. In a voyage up the Irish Sea, in 1913, Lieutenant Hunsaker and I observed scores of gulls gliding to and fro on the windward side of our vessel in a fairly stiff breeze, while elsewhere, near and far, only flapping flight occurred. Presently the vessel nosed directly into the wind and promptly the marvellous soaring maneuvers all ceased.

Returning across the North Atlantic I stood on the after-deck in a strong head-on gale watching the efforts of smaller gulls to soar among the tumultuous billows well behind the vessel. At times they nearly succeeded. But prolonged passive flight they could not maintain. Unfortunately no albatross was there to demonstrate his supreme art amid the roar and confusion of the elements.

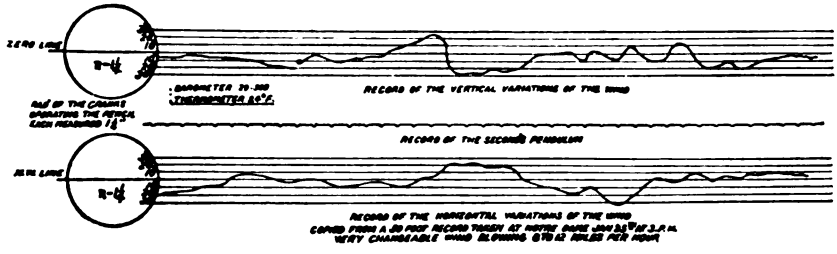

FIG. 2. RECORDS OF WIND VARIATION IN HORIZONTAL AND VERTICAL DIRECTION BY A. F. ZAHM, 1893

In case (2) of the fixed up-current any flying creature can easily soar indefinitely. The prime essential is that the upward component of wind velocity shall equal or exceed the slowest possible rate of descent in gliding down by gravity in still air. Not infrequently one may observe the vulture pause above some gently sloping hill and float there stationary, maybe for the pleasure of floating or to rest and relax on his airy perch. The American eagle I have observed soaring serenely in the most dreadful places; now plunging from his nest above Shoshone Cataract, to explore the precipitous gorge; now riding the blast over Pike's Peak; now wheeling above the Grand Canyon of the Arkansas; and always with the same majestic grace, without wing beat or perturbation or apparent effort. Humboldt tells us the condor can raise him-

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self up from the Pacific and in no long time outsoar the Andes—a pleasant challenge to his brother homo! Well back in the nineteenth century all such evolutions were correctly explained and affirmed to be imitable by man. The twentieth century has already seen him perform like maneuvers on an imposing scale.

But to the expert sailor, bird or man, mere flotation on a secure and stationary elevator is not long exhilarating. The real sport is to soar across country by aid of the invisible convection currents. These are very abundant over favorable terrene with strong sunshine. All lofty heated slopes, particularly if steep and barren, may produce updrafts of ample power for sustained gliding. On a blazing summer day I have stood on a high hill top and heard the wind murmur up through the forest, like a draft in some great flue, bearing the dead leaves far aloft and with them the buzzard who from that elevation could scour the neighboring fields till he encountered a new ascending current. Over the desert numerous columns of sand reveal the rising vortices continuously. And invisible ones too are there. Every isolated cumulus or thunder cloud marks the top of an uprushing air column either now or recently active. One bright morning on a Texas plain, east of El Paso, I saw a sudden white cumulus pop out in the clear sky, drift southward and quickly dissolve away. Presently another a few thousand feet further duplicated that weird performance. How many viewless vortices, per square mile, were pouring up from that sunburnt plain?

And what is the vertical speed at the center of a vortex or seething cumulus or heat thunder cloud? Dr. G. C. Simson answers:[5] "We can easily calculate the upward velocity necessary to support a hailstone of a given size, and as we know that every hailstone has been supported, we get at once a measure of the upward velocity. Hailstones of half an inch diameter are very common, and these need an upward current of 33 feet per second (22 miles per hour). Hailstones as big as pigeon eggs, and even as big as hen eggs, are frequently reported. These indicate ascending currents of enormous velocities, regular vertical hurricanes, in which no aircraft could survive for a fraction of a minute."

[5] "Thunderstorms and Aviation," *Jour. Roy. Aer. Soc.*, Vol. XXIX, 1925.

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The sustension speeds v_1, v, for similar stones having weights ar^3, an^3r^3, and lifts br^2v^2, $bn^2r^2v^2$, bear the ratio $v/v_1 = \sqrt{n}$; hence diameters of $\frac{1}{32}$, $\frac{1}{8}$, $\frac{1}{2}$, 2, 4 inches by Simson's data need uprush speeds of, 5.5, 11, 22, 44, 66 miles an hour. Moderate cumuli are not so dangerous. Some balloonists, sucked into thunder clouds, have been tossed violently about; pelted with hail, snow and rain; but suffered nothing worse than sea sickness; others, however, have lost their lives. Aircraft should avoid them, as Simson well explains.

The hen-egg size is not extraordinary. At Annapolis hailstones large as baseballs once roared down upon the Naval Academy; at Potter, Nebraska, fell one like a grape fruit 17 inches in circumference by actual measurement. But the report from India of hail big as an elephant, needs prayerful meditation; for, granted a tornado can support such weight, what can support the tornado long enough for the growth of a two-yard stone? Showers of frog and grape fruit, yes; but elephant showers, "hell and damnation, oh!", as Othello said of his wife. In season perhaps the Himalayan draft might sustain a 20-ton Fokker.

Of timely interest now is the long aerial swell that leads the thunderstorm. When the shower-cooled air under the advancing rain cloud sinks earthward it drives the warm air forward in a powerful uprush manifested by ascending dust and leaves. "When will aviators make this the scene of their adventurous frolic, careering playfully before the brow of the tempest and the harmless rage of the lightning, sailing perhaps with slackened motive power, yet swift and secure as the storm-riding petrels at sea?" This question, written twenty years ago in my book, "Aerial Navigation," is still pertinent in America though less so in Europe where the glider's art is further advanced.

Of all soaring evolutions, that of the vortex-riding vulture, so uncanny and curious to the uninitiated, is perhaps the most commonplace and familiar; for that invisible Jacob's ladder, the dry whirlwind, essential vent of the earth's atmosphere, abounds generally over the landed globe where strong sunlight prevails. If the rising column is vertical in a stagnant atmosphere, the

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loitering scavenger or restless bird of prey wheels round in circles, spiraling ever upward on a helical path to any desired altitude, then choosing his course glides directly across country to his intended goal. If the air is not stagnant, the ascending column drifts with the wind, changing the circles to trochoids in horizontal plan, while the bird maintains or increases his elevation at will.

Thus surveying the earth for his daily sustenance, the majestic carrion hunter, clumsy afoot but sublime on high, sweeps all

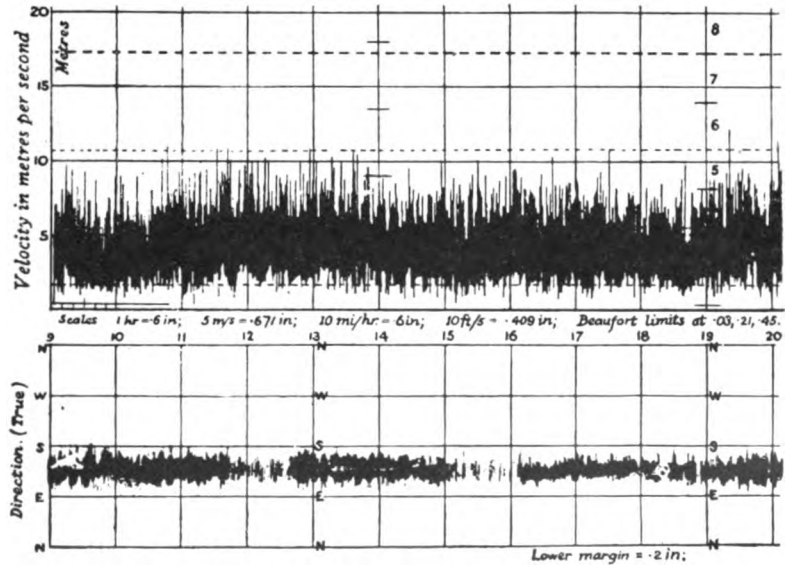
Velocity in metres per second
Metres
Scales 1 hr = 6 in; 5 m/s = ·67 in; 10 mi/hr = 6 in; 10 ft/s = ·409 in; Beaufort limits at ·03, ·21, ·45.
Direction. (True)
Lower margin = ·2 in.

FIG. 3. ANEMOMETER RECORD AT PACKHILL, DYCE, SEPTEMBER 26, 1922

day over wilderness or burning desert, from elevator to elevator; now shaving the soil in level glide, now mounting the empyrean on lordly wing, the envy of man below. At Toluca one sees the sacred birds of Mexico, at 10,000 feet above the sea, patrol perpetually with the same apparent ease as in the lowland by the coast. And the great tawny vulture of Africa, perched on the mountain top; big as a sheep, morose, silent, awaiting the dawn; how Mouillard loved to watch him shake the dew from his vast plumes and, with never a beat of those grand pinions, soar godlike through immensity!

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When I questioned Wilbur Wright whether he or anyone could so ride the aerial vortex, he affirmed that his glider had quite the efficiency of your turkey buzzard, but probably would not turn readily enough to emulate him in the usual whirlwind of small diameter, but might even beat him in an upsloping breeze; for both had coasted down the Kill Devil sand hills in friendly competition, and with the count slightly in Wilbur's favor. German experience with long-winged gliders seems to corroborate Mr. Wright's opinion.

SOARING COMPETITIONS

Prior to 1920, for more than a century, passive bird flight had been fairly understood and to some extend initiated by man. Indeed the early designers of airplanes, notably from 1893[6] to 1903, owed much of their success to experiments with model or full-scale gliders. Then for nearly two decades the dynamic airplane, propelled by a glorified automobile engine, diverted attention from the old time aim to rival the sea gull, stork or vulture.

As the treaty of Versailles restricted the output of dynamic aircraft in Germany, airmen there are said to have felt unusual stimulus to perfect motorless flying machines. However this be, in 1920 they organized a sailing contest that resulted in numerous prolonged glides down the slopes of the Wasserkuppe, a Rhön-district mountain rising 2000 feet above the plain to the north, and surrounded by smaller hills. Next year this practice developed into cross-country soaring. In 1922 crowds on the Wasserkuppe slopes saw pilots soar for hours above them; now near enough for conversation, now lifted 1000 feet upward; disporting themselves in any wind up to 45 miles an hour.

A wonderful flight was made for the Milesburg prize, by Herr Nehring of the Darmstadt college glider team. Having climbed

[6] At about this time Goupil, in France, patented and described in his book an airplane with the present-day system of control; viz., two ailerons, a vertical and a horizontal rudder. From his description a Goupil airplane was built in 1916, and successfully flown, to demonstrate the prior art, for use in the Wright vs. Curtiss patent suit. In 1903 Langley and the Wrights completed their airplanes; the first competent to fly but injured in launching; the second flown successfully December 17, 1903.

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500 feet above the Wasserkuppe, he sailed across wind, over the intermediate valleys and hills, to the ancient Milesburg rock castle, 7 miles distant; then by clever soaring along the windward slopes of other hills, regained altitude enough to return within 400 feet of his starting point.

At the 1926 meeting, pilot M. Kegel was purposely caught in a thunderstorm, carried 4000 feet upward and 40 miles through space, eventually heading leeward and landing safely, after three-quarters of an hour's violent tossing in the aerial whirlpool, unable to see through the dense and turbulent cloud mass. This was a fair trial in the project of eventually sailing from cloud to cloud.

Meantime Rossiten, on the Baltic coast of east Prussia, became

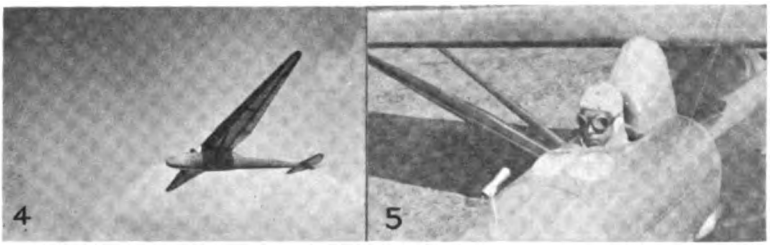

FIG. 4. THE KROENFELDT GLIDER "WIEN"
FIG. 5. KROENFELDT IN HIS GLIDER "WIEN"

a soaring center where pilots could glide many miles along the sand dunes and return to their base. Duration records were made by cutting figure eights in the ascending sea breeze. In 1924 F. Schultz sailed there more than 12 hours; in 1927 he stayed aloft 14 hours 7 minutes. Later he soared 9 hours with a passenger.

Following the German lead many foreign countries, France, England, Russia, Italy, Switzerland, organized soaring contests with like success.

Under promotion of a soaring society the Wasserkuppe now has annual competitions accessible by automobile; also a research institute, glider schools, a student colony operating all year round. Last August, 1929, 25 gliders took part in the contests. Mr. Ide

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of the National Advisory Committee for Aeronautics reports as follows:

"The outstanding feature of the meeting was the development of cloud flying. Thus with very slight wind (6 ft. per sec.), and using only heat currents, Groenhof climbed to 1750 feet above his starting point. Soaring in front of a storm, Hirth climbed to 3300 feet. Kroenfeldt broke all records by a flight of 143 kilometers (89 miles) to Hermsdorf, near Jena, during which he reached a height of 1940 meters (6400 feet). Later he surpassed his own record by a flight of 150 kilometers (93 miles) to Lienlas, near Bayreuth, attaining on the way a height of 2160 meters (7080 feet) above the starting point. This performance was especially remarkable in that it was not accomplished by aid of a storm, but by the energy stored in cumulus clouds. Hirth made a closed-circuit record by flying to the Schweinsberg, a point which he had previously selected, 6.2 miles from the Wasserkuppe, and returning without intermediate landing. Another remarkable flight was that of Groenhof who, carrying a passenger, flew to Nordheim near Meiningen, 21 miles away, and reached a height of 4330 feet."

Kroenfeldt's Wien, Figures 4, 5, has the following dimensions in feet; length 21.3; wing span 64; mean chord 2.7; height 3.3. Its lift to drag ratio is reported to be 24 to 1, a remarkable value due to excellent stream-lining and extraordinary slenderness of wing.

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THE ORIGIN OF THE MID-ATLANTIC RIDGE

HENRY S. WASHINGTON, Ph.D.

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The ocean-basins differ much in their general characters.[1] Besides the comparatively few coral islands, which are supposed to have been built on sunken or sinking submarine volcanoes, the truly oceanic or deep-sea islands are all entirely volcanic, with one exception. The lavas of these volcanoes in all the oceans are very predominantly basalt, but with constant although very subordinate amounts of alkalic lavas, mostly trachyte and basanite. In this respect the lavas of the Atlantic Basin are relatively slightly more alkalic than those of the Pacific and Indian Oceans.

The oceans differ also in the general configuration of their floors. That of the Indian Ocean is at a comparatively shallow depth and is quite level; there are few volcanic islands and these are widely scattered and with little evidence of systematic arrangement.

The largest ocean-basin, that of the Pacific, is the deepest, with an average depth of about 15,000 feet. Its floor is, on the whole, rather level, but with strongly marked and systematic diversities. Over much of it are many long and narrow submarine ridges, on which stand a multitude of volcanic islands with fewer coral islands. These linear island-groups have a general and fairly uniform trend of west-northwest and east-southeast (N. 62°W.), and their platforms are submarine mountain-ranges, which are regarded as a wrinkling through pressure of the crust that forms the floor. At the north, in the Aleutian Islands, and along the east coast of Asia is a series of island "arcs" or "festoons," also produced by tangential pressure of a different origin. Fringing many of these island ridges and the island arcs are long narrow "deeps."

The Atlantic Basin differs from both of these oceans in the

[1] The Arctic and Antarctic Oceans are not considered here.

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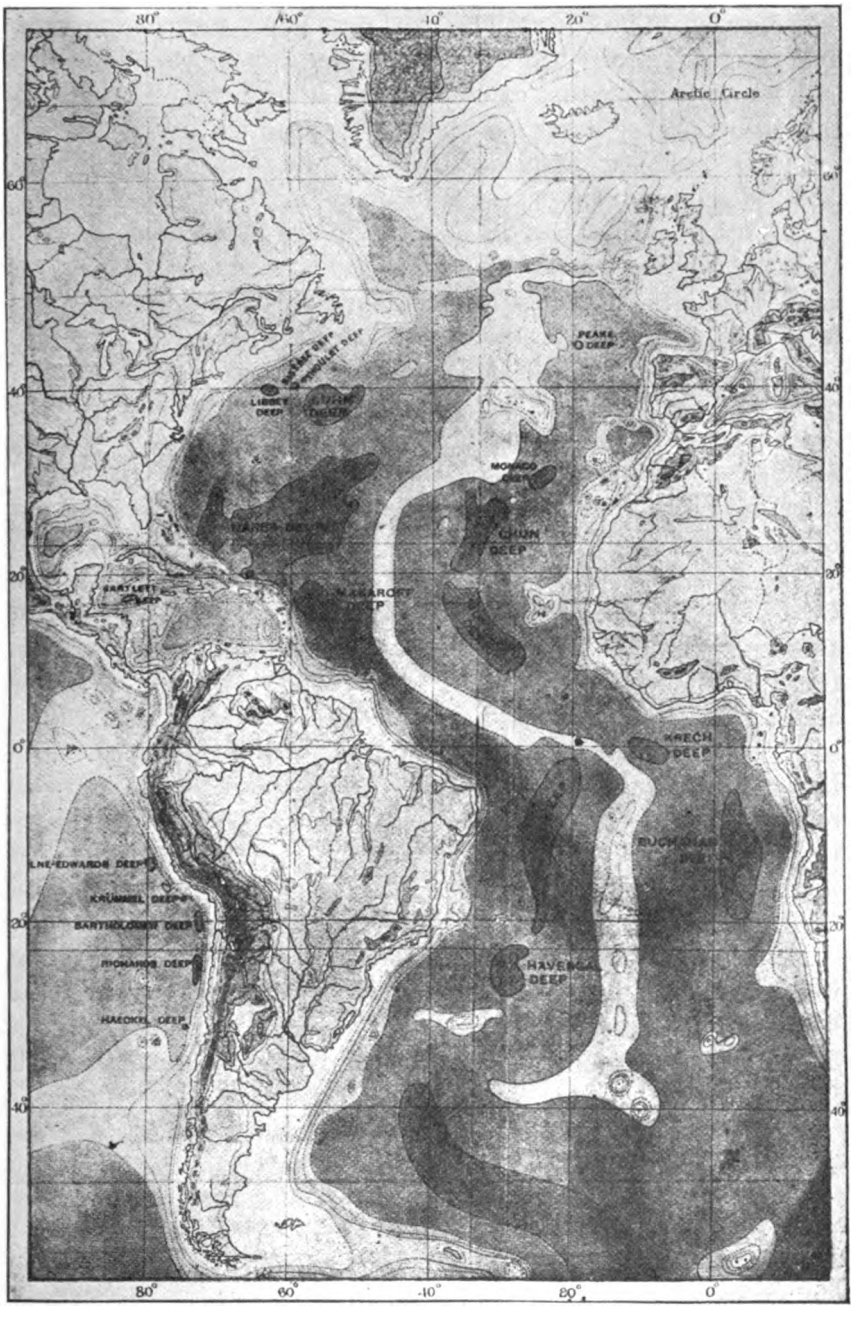

Photo. by J. Harper Snapp

FIG. 1. The Mid-Atlantic Ridge. (After Sir John Murray.) The position of St. Paul's Rocks is shown by a dot. (From F. B. Taylor, Bull. Geol. Soc. America, Plate 4.)

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configuration of its floor. The most prominent, most interesting, and most significant feature of the Atlantic Basin is a long and rather narrow ridge that extends almost continuously from about the 50th parallel north to about the 40th south (fig. 1). It forms an S-shaped figure down the middle of the ocean, about mid-way between the two shores and almost parallel with the coasts to the east and west. This is known as the Mid-Atlantic Ridge or the Mid-Atlantic Swell or Rise. Alongside parts of its length are interrupted and roughly parallel "deeps." I quote here Taylor's excellent summary of its main features:[2]

"The persistence with which this feature maintains a medial position in the ocean bed for nearly 9000 miles (following its great curves) is very striking, and the position which it takes in passing between South America and Africa is still more remarkable. The Ridge is a submerged mountain range of a different type and origin from any other on the earth. It is apparently a sort of horst ridge—a residual ridge along a line of rifting or parting—the earth-crust having moved away from it on both sides. On the chart it is indicated to be mostly less than 2000 fathoms (12,000 feet) beneath the sea, with some parts less than 9000 feet and a few volcanic islands which rise 3000 or 4000 feet above the sea. Its general height above the surrounding ocean floor is between 3000 and 6000 feet, with a few island peaks rising 18,000 or 20,000 feet. Between South America and Africa the ridge runs east-southeast through 40 degrees of longitude (nearly 3000 miles), and in this part is parallel with the adjacent continental border of South America."

Scattered on and along this Ridge are the wholly volcanic islands and island groups of the Azores, Ascension, Tristan da Cunha, Gough, and Bouvet, while St. Helena lies near its eastern edge, southeast of Ascension. All these islands, it must be noted, are built up entirely of volcanic lavas.

But besides these volcanic islands there stands on the Ridge a most remarkable, indeed unique, small group of four rocky

[2] F. B. Taylor, *Bull. Geol. Soc. America*, **21**, 217, 1910.

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islets, the largest about one-eighth of a mile long, the highest point being some 64 feet above the sea-level. This lies in the middle of the Atlantic, in latitude 0° 55′ 28″ north and longitude 29° 22′ 32″ west. It is named St. Paul or St. Paul's Rocks, and our attention will be largely devoted to it, because of its importance for the study of the Mid-Atlantic Ridge. The portion of the Ridge on which St. Paul lies is the rather short and narrow

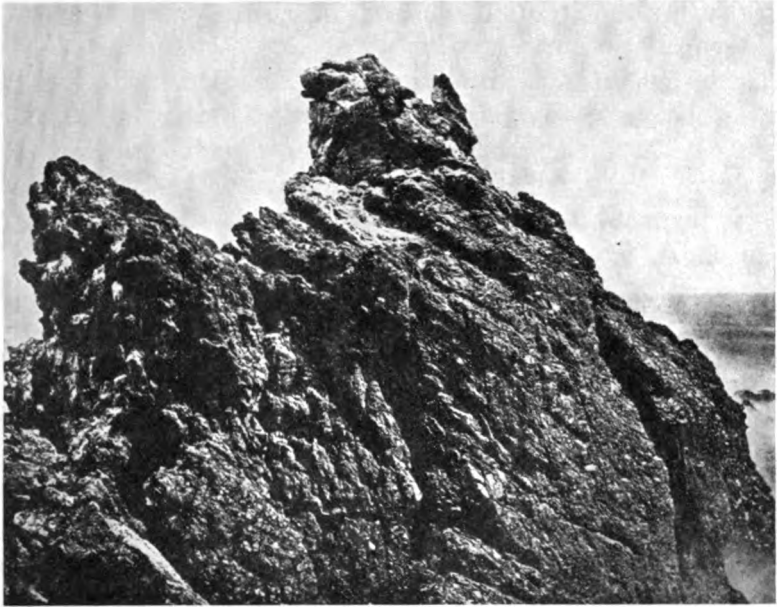

FIG. 2. The Peridotite of St. Paul's Rocks. (From the Narrative of the *Challenger* Expedition. The schistose texture should be noted.)

stretch that runs almost east and west near the equator, and there is a break in the Ridge near the island group.

The great interest and importance of St. Paul is that, lying in the middle of the Atlantic Ocean, it is unique among oceanic islands in being made up, not of lavas and other volcanic rocks, but of a plutonic or deep-seated igneous rock, a peridotite composed of olivine with a little pyroxene, which is named

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wehrlitic dunite.[3] This rock is, furthermore, remarkable because it is metamorphosed by great pressure. This is shown by its schistose texture as seen in the thin microscopic section and in the mass (fig. 2). The rock is, indeed, so remarkable among oceanic island rocks that Darwin declined to classify it, but its true character and its metamorphic texture were long ago pointed out by Renard.[3a] Such textures, produced by pressure, are very usual with peridotites, but are never found with the volcanic lavas of the oceanic islands, when examined with the microscope.

The origin of the Mid-Atlantic Ridge, which Taylor calls "one of the most remarkable and suggestive objects on the globe," is a much disputed problem, one as yet unsolved, at least with certainty.

It is regarded by Haug[4] as an axial rise in the great Atlantic geosyncline, a median anticline formed by the beginning of crumpling. According to Taylor[5] it is a horst, a portion of the original crust that "has remained unmoved, while the two continents on opposite sides have crept away in nearly parallel and opposite directions."

This is essentially the view of Wegener,[6] who thinks it to be "the former floor of the rift-valley which was in existence during the period when the Atlantic Ocean was composed of a relatively narrow fracture, which was subsequently filled with sunken margins, shore deposits, and also partly molten sial." Wegener regards the islands that crown the Ridge as "*certainly*" fragments of the margins of the rift. He does not mention the existence of

[3] The rock of St. Paul was first described petrographically by A. Renard in the *Challenger* Reports in 1882 and also in other papers. The specimens collected by Dr. G. Vibert Douglas on the Shackleton-Rowett (*Quest*) Expedition in 1921 were intrusted to me for study, and I am deeply indebted to him and to the Trustees of the British Museum for this privilege. The detailed results, with a chemical analysis of the rock, will appear shortly in the report of this expedition. Some of the conclusions as to the origin of the Ridge are stated in this report.

[3a] A. Renard, Neues Jahrb., 1879, p. 39); Voyage of *Challenger*, Narrative, II, Appendix B, 1882; Ditto, I, (1), p. 206, 1885.

[4] E. Haug, "Traité de Géologie," **1**, 164, 1907.

[5] Taylor, *Bull. Geol. Soc. America*, **21**, 218, 1910.

[6] A. Wegener, "The Origin of the Continents and Oceans," p. 61, 1924.

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the St. Paul group and the peculiar and highly significant character of its rocks, or their bearing on the problem of the origin of the Mid-Atlantic Ridge.

Daly[7] thinks that it may "conceivably represent a long strip of the original continent, a strip left behind when that continent was torn into fragments, which slid away, respectively to westward and to eastward. Other masses, like the rugged pile of the Azores, may also represent sunken pieces of the original continent."

Molengraaff[8] supposes the Ridge to be "nothing but a cicatrix of the former rent or fracture, along which the disruption of the American continent from the European-African continent took place." He compares it to the great rift-valley in East Africa, and both he and van der Gracht,[9] who is inclined to agree with him fully, explain the high positive gravity anomalies along the Ridge observed by Hecker and Meinesz by the extrusion of basalt.

The latest contributor to the discussion is Gregory,[10] who, in his address on the geological history of the Atlantic Ocean, leaves one somewhat in doubt as to his views on the origin of the Ridge. He states that: "According to the view that they are folds, the Mid-Atlantic Rise would be an anticline between two geosynclines," (which is essentially the view of Haug), although he doubts this interpretation. He also records his belief that the Atlantic trough is not a fold-valley, but he does not explicitly decide on either of the three explanations that have been offered for the undulations of the floor of the Atlantic Basin. He regards the undulations of the Atlantic Basin as having a lattice-like structure.

It will be seen that the origin of the Mid-Atlantic Ridge has been attributed to two main causes, with some differences in detail. One is that it is the result of *compression*, with the forma-

[7] R. A. Daly, "Our Mobile Earth," p. 280, 1926.

[8] G. A. F. Molengraaff, in "Theory of Continental Drift, a Symposium," p. 91, 1928.

[9] Van der Gracht, "Theory of Continental Drift," p. 210.

[10] J. W. Gregory, *Quart. Jour. Geol. Soc.*, **85**, cxiii, 1929.

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tion of an anticlinal fold; the other, based on the hypothesis of continental drift, is that the Ridge represents the original scar or fissure formed by *tension* when the continental fragments drifted apart. The two ideas are diametrically opposed.

It is a striking fact that not one of the authorities cited, who include the authors of the most important papers on the subject, mention the islets of St. Paul and their most peculiar and unique rock, which are a very important factor in the problem. Darwin, as far back as 1844,[11] was so impressed by the peculiar character of the rock, which he recognized as not volcanic, that he hesitates

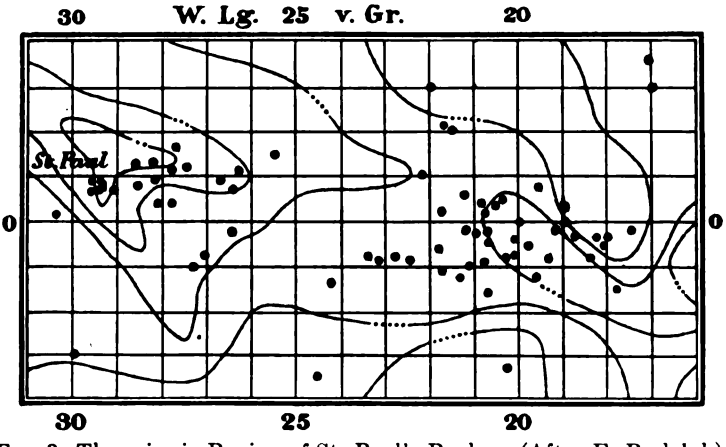

FIG. 3. The seismic Region of St. Paul's Rocks. (After E. Rudolph)

to include St. Paul's Rocks among the volcanic islands of the ocean. Their metamorphic character was pointed out in 1882 by Renard, as we have seen. It seems to me that this little group is practically decisive in explaining the origin of the Mid-Atlantic Ridge.[12]

The St. Paul's Rocks lie in a very unstable area of the Atlantic Ocean. This has been pointed out by Suess,[13] who called atten-

[11] Darwin, "Geological Observations on Volcanic Islands," 2d ed., p. 37, 1891.

[12] This hypothesis as to the formation of the Ridge is suggested in my chapter on "The Petrology of St. Paul's Rocks" in the forthcoming report of the Shackleton-Rowett, *Quest*, Expedition.

[13] Suess, "Das Antlitz der Erde" (English translation by Sollas), **4**, 601, 1909.

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tion to the high degree of seismicity and submarine volcanicity of the region around the group, as shown by the data assembled by Rudolph[14] from ships' log-books. Rudolph himself[15] mentions this and names the narrow belt on both sides of the equator between 16° and 31° west longitude "die seismische Zone des St. Pauls-Felsen," giving a map which is reproduced in figure 3. The group lies on the short, narrow, east-west section of the Ridge, near a break in it, and near the north end of the Tizard Deep.

The rock of which the islets are composed is not volcanic, but is a plutonic dunite, and it has been *metamorphosed by pressure.* It is evidently a portion of the solid crust that forms the ocean-floor. It is not a xenolith or included block brought up from below by volcanic action, as is shown by the absence of any trace of lava on the islets and by the size of the mass of the whole group.

The only conceivable ways by which the rock could have been raised to the surface of the sea are by a regional vertical movement from below of this part of the Ridge or by lateral pressure. Of these, the former may be dismissed, as such extremely narrow and localized uplifts, through many thousand feet and unsupported on the sides, are unknown elsewhere and are indeed highly improbable, if not impossible. Long narrow graben, such as those of East Africa and the continuation through the Red Sea and the Jordan Valley, are much wider and they are down-drops, not uplifts. This leaves lateral pressure as the sole competent cause of the uplift of this part of the Ridge, which is quite in accord with the known condition of instability and present-day seismic and submarine volcanic activity of the region. It also accords with and explains the squeezed texture of the rock. If this is true of the St. Paul section, it may reasonably be regarded as true of the whole Ridge, which is thus to be considered as the result of compression, not of tension or as a residium of continental drift.

The Ridge must then be in the nature of the crest of an anti-

[14] Rudolph, Gerland's *Beitr. Geophys.*, **1**, 302, 1887, and later volumes.
[15] Rudolph, *Op. cit.*, p. 229 and Tafel VII.

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cline, as was suggested by Haug. This would account also for the presence of volcanoes all along the Ridge as well as, indeed much better than, the fissure of an original continent. It is to be noted that these volcanoes lie along the axis of the Ridge, with the exception of St. Helena, whereas Wegener speaks of them as being at the sides of the fissure.

To account for the peculiar shape of the Ridge and its median position between the two coasts and its parallelism with them it is tempting to invoke the hypothesis of Prinz,[16] in which he explains by differential torsion of the northern and southern hemispheres the obliquity and other features of the American and Eurafrican Continents, and of certain trend-lines of Australia, the Malay Arc, and others in Asia. Dana speaks favorably of Prinz's hypothesis and it is mentioned by Taylor,[17] who dismisses it from consideration rather summarily. It should be noted, however, that the St. Paul section of the Ridge, running east and west, in a region of great seismic and submarine volcanic activity, is what might be expected on Prinz's torsion theory. It would represent a sort of knot, the line between the differential eastward and westward torsional movements on the south and on the north.

If there is any truth in the tetrahedral earth, such as was first suggested by Lowthian Green, and as has been advocated by Emerson, Hobbs, and others, the solid masses so formed would add their effect to any such differential torsion by their resistance in the northern hemisphere.

It is unnecessary here to dwell on this hypothesis, but it should be added that Prinz cites the markings on Mars and on Jupiter in its favor, and I might say that the differential zonal rotation of the sun parallel to its equator[18] also adds valid support to its possibility.

At any rate, in these days of hypotheses of the splitting and drifting apart of continental masses, the shifting of the poles to

[16] W. Prinz, *Annuaire Observ. R. Bruxelles*, 1891, See J. D. Dana, "Manual of Geology," 4th ed., p. 395, 1895. I have not had access to the original paper.

[17] Taylor, *Op. cit.*, p. 217.

[18] H. N. Russell, et al., "Astronomy," pp. 192–194, 1926.

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the vicinity of the equator at various periods, hypotheses of sunken land-masses and bridges, erected to explain difficult problems of animal and vegetal distribution by problems that are still more difficult of explanation, and the great crustal movements and turnings, with slippings-down of the crust over downward slopes that may not exist, as imagined and invoked by Suess, Daly, Wegener, Taylor, and many others, Prinz' hypothesis cannot or should not be considered as fantastic, but is certainly deserving of respectful consideration, as is any hypothesis that was regarded seriously by James Dwight Dana.

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MAKING CANNON BY THE COLD WORKING PROCESS AT WATERTOWN ARSENAL*

T. C. DICKSON

Colonel, Ordnance Department, U. S. A.

For over a half century the Springfield Armory cold worked each rifle barrel it made. After drilling and first reaming each barrel, a sub-chamber was formed in which a cartridge was fired that gave a pressure of at least one and one-half times the service pressure. This high pressure permanently enlarged the chamber and the rear part of the bore, and increased the elastic limit of the steel.

After the World War, the Watertown Arsenal investigated the practicability of making cannon by the cold working process. Equipment was designed for compressing water to as high as 150,000 pounds per square inch, and conveying it into and retaining it in the bore of a cannon. A device for accurately measuring the pressure applied was perfected. Experiments were conducted with cylinders having a ratio of outside to inside diameters of from $1\frac{1}{2}$ to 4. The permanent enlargements of the outside and inside diameters and also of intermediate diameters, produced by various pressures applied in the bore, were measured. Empirical formulae were deduced from numerous data for designing cannon. These formulae include the elastic limit of the steel to be cold worked. The higher the elastic limit the greater will be the interior pressure required to produce a specified permanent bore enlargement to a given size of cylinder.

If the pressure applied in the bore of a cylinder of gun steel be increased by successive increments and each pressure be plotted as an ordinate, and the corresponding increase in any diameter of the cylinder (called dilatation) be plotted as an abscissa, the

* Communicated by Major General C. C. Williams, Chief of Ordnance. U. S. A. Received for publication December 14, 1929.

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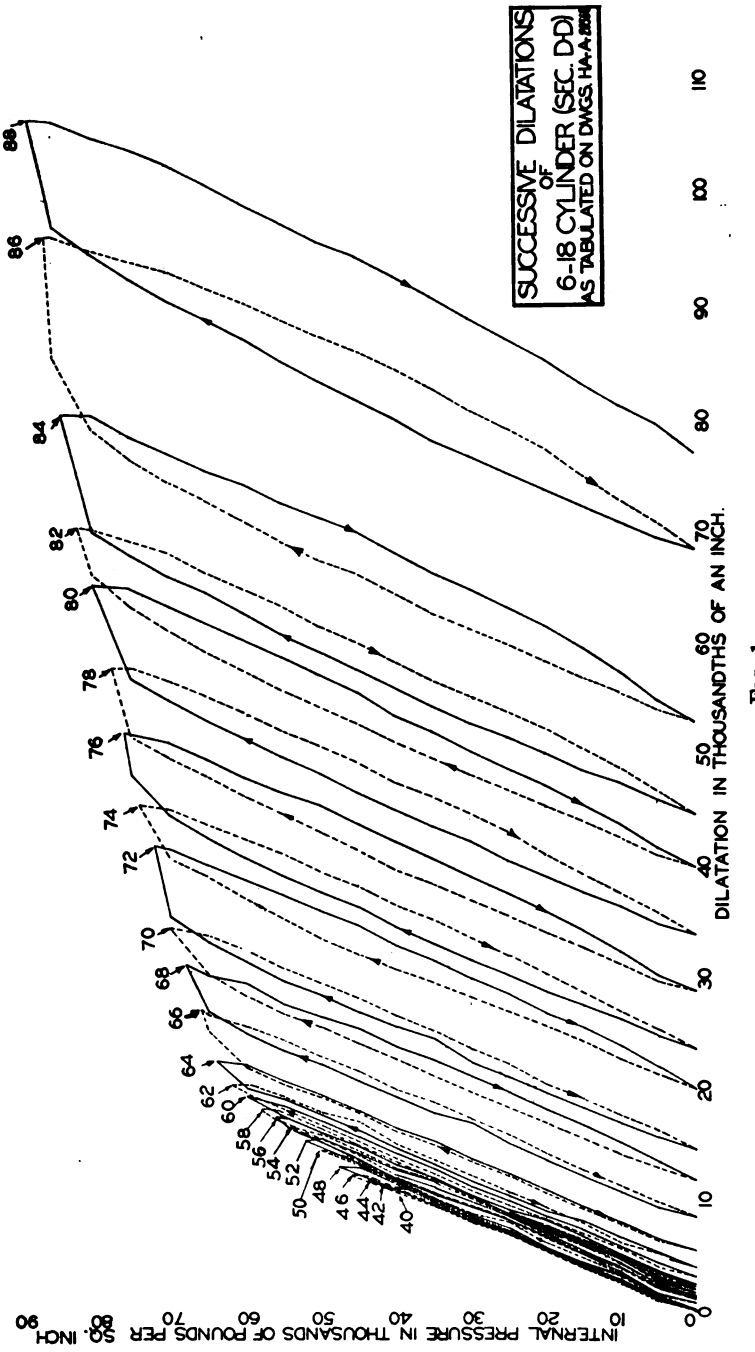
SUCCESSIVE DILATATIONS OF 6-18 CYLINDER (SEC. DD) AS TABULATED ON DWGS. HA-A-[illegible]
DILATATION IN THOUSANDTHS OF AN INCH.
INTERNAL PRESSURE IN THOUSANDS OF POUNDS PER SQ. INCH

FIG. 1

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resultant curve will be similar to that shown in figure 1. The load-dilatation curve is a right line until the steel is stressed beyond its original elastic limit; as the pressure is further increased the dilatation increases at a more rapid rate than the applied pressure. After plastic flow occurs, if the pressure is reduced by decrements to zero and then increased by increments, the load-dilatation curves will form a loop, due to hysteresis, as shown on

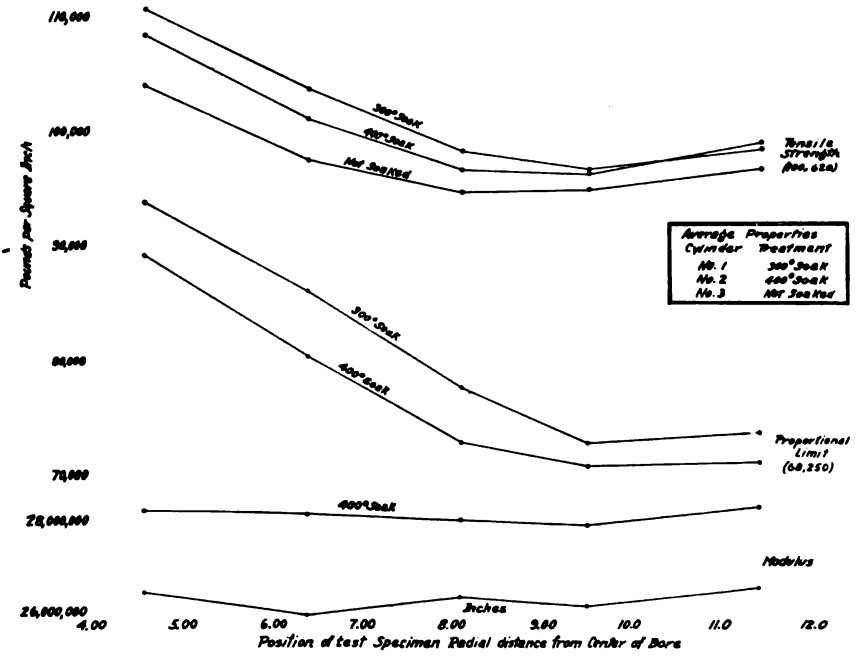

FIG. 2

figure 1. If the pressure is repeatedly reduced to zero and then increased to the same amount, the two branches of the curves will approach and finally coincide on a right line. If the cylinder is given a low temperature anneal from about 250° to 400°C., the stress-dilatation curve will be a right line. Repeated applications of the same pressure or a low temperature anneal remove hysteresis. Neither the time taken to attain the maximum pressure nor the application of that pressure by increments or by a one con-

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tinuous increase affect the amount of permanent enlargement of the bore.

Cold working, or permanently enlarging all diameters of a cylinder by interior pressure, produces an internal strain of tension in the exterior portion of the wall thickness and of compression in the interior portion of the wall. This has been called "self-hooping." A low temperature anneal at from 250°

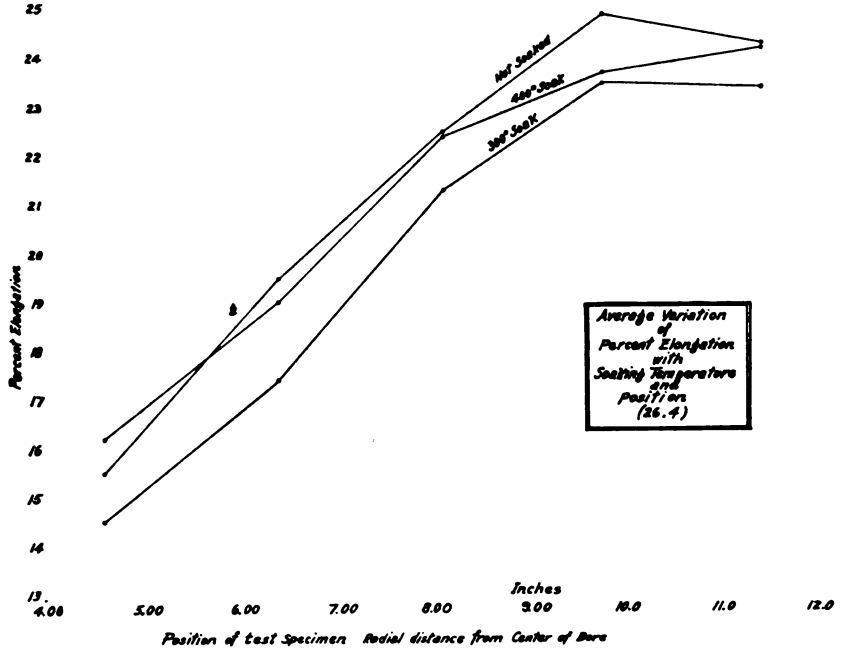

FIG. 3

to 400°C. after cold working removes the initial compression of the bore.

If a cylinder is permanently enlarged by pressure applied in its bore, the increase in any diameter, expressed as a percentage of what that diameter was originally, will be a maximum at the bore and a minimum at the exterior diameter. Increasing the diameters of a steel cylinder by this method increases the elastic limit and tensile strength and decreases the elongation, contraction of area and Charpy, somewhat in proportion to the amount

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of permanent deformation. Cold working increases appreciably the pressure that can be repeatedly applied to the bore of a steel cylinder without additional permanent enlargement. This increase in strength results principally from the increase in the elastic limit and only partially to the initial compression given to the metal adjacent to the bore.

Stress-strain diagrams of tangential tensile test specimens taken from a cannon after it has been cold worked are curves; the elastic limit and modulus of elasticity cannot be determined.

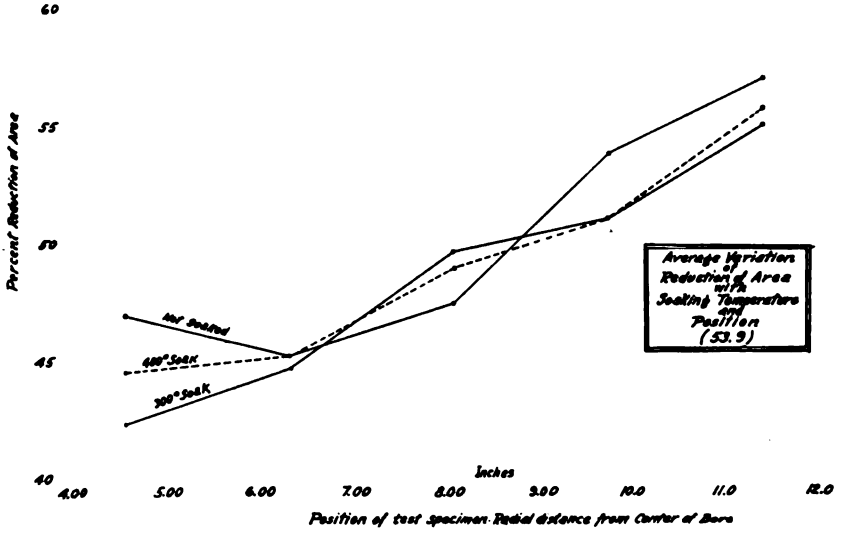

FIG. 4

If the cannon is given a low temperature anneal between 250°C. and 400°C. after it has been cold worked, the stress-strain diagram will be a right line. A low temperature anneal at 300°C. after cold working makes the strength of a cannon about 11 per cent greater than that of the same cannon that is not low temperature annealed after cold working. If given a low temperature anneal at 400°C., the strength will be the same as after it is cold worked.

The amount of permanent enlargement given cannon by cold working does not change measureably the density of the steel;

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it does shorten the length of the cannon, the amount of shortening being the greatest next to the bore and least at the exterior diameter. If the wall is thick, the ends become concave.

The hardness of the steel in a cylinder that has been cold worked is greatest near the bore and decreases regularly and appreciably to the exterior surface. The grains adjacent to the bore are elongated tangentially while no change has been noted in those adjacent to the exterior surface.

The amount of permanent enlargement that can safely be

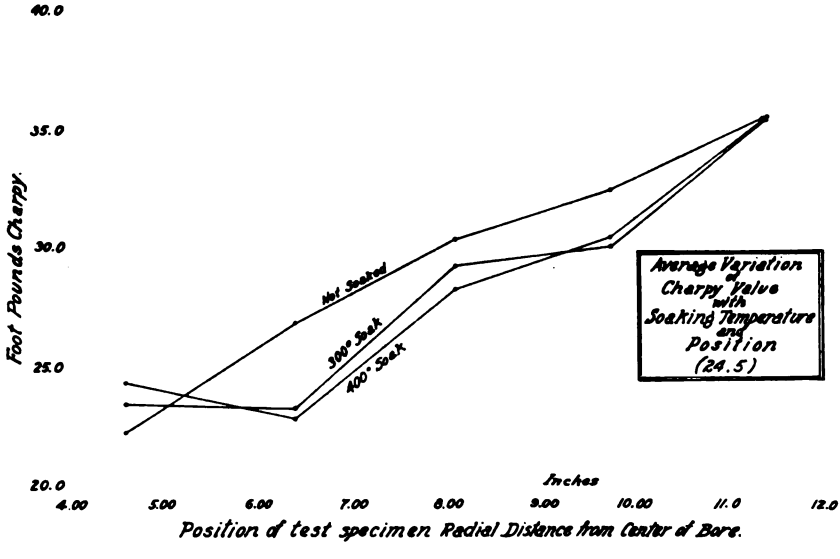

FIG. 5

produced in a given design of cannon is limited by the ductility of the steel, as determined by the elongation, contraction of area and particularly by the Charpy. Making cannon by the cold working process has resulted in prescribing a Charpy test for all forgings for cannon.

Six gun forgings from the same heat of steel were machined to the same dimensions and cold worked so their bores were enlarged practically the same amount. After cold working, three (item 1) were given a low temperature anneal at 300°C. and the other three

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(item 2) were not annealed. Table I gives the average physical properties of the three forgings in each group before they were cold worked and after one group was cold worked and the other group was cold worked and low temperature annealed.

A steel cylinder, having an 8-inch bore, a 24-inch exterior diameter and a length of 5 feet, was cold worked so its bore was permanently enlarged 8 per cent. Three sections, each 9 inches long, were cut from the center part of the cylinder; section No. 1 was low annealed at 300°C., section No. 2 was low annealed at 400°C., and section No. 3 was left in its cold worked condition. Four (4) tensile and eight (8) tensile Charpy test specimens

TABLE I

ITEM	ELASTIC LIMIT		PER CENT INCREASE	TENSILE STRENGTH		PER CENT INCREASE	ELONGATION		PER CENT DECREASE	CONTRACTION		PER CENT DECREASE	CHARPY		PER CENT DECREASE
	Original	Final		Original	Final		Original	Final		Original	Final		Original	Final	
1	68,250	96,350	41	105,583	118,833	12.5	19.6	13.9	28	40.4	35.6	11	29.6	21.5	27
2	69,330			104,375	113,913	9	22.2	15.3	31	44.1	42.1	4.6	32.6	26.4	19
3	68,250	94,100	38	100,620	107,800	7	26.4	14.6	45	53.9	42.5	21	24.5	23.7	3
4	68,250	89,900	31	100,620	108,900	8	26.4	16.3	38	53.9	44.7	17	24.5	24.5	0
5	68,250			100,620	104,400	3.7	26.4	15.6	41	53.9	47.1	13	24.5	22.4	8.5

were taken tangentially at each of five (5) radii from each section; the radii were the same in each section. The average values obtained at each radius from each of the three sections are plotted on curves 3, 4 and 5. The average physical properties of the forging before it was cold worked and the averages obtained from each of the three sections at 4.6 inch radius are given as items 3, 4 and 5 in Table I with the percentage changes. The results show that a low temperature anneal after cold working increases the modulus of elasticity, the elastic limit and tensile strength (300°C. giving a greater increase in elastic limit and tensile strength than 400°C.) but tends to decrease the elongation, contraction and Charpy.

Table I shows that the elastic limit of the steel adjacent to the bore of a cannon is increased about one third and the tensile

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strength about 8 per cent, while the elongation may be decreased nearly one half and the contraction of area and Charpy by about 25 per cent. A tensile test specimen having a 2-inch gauge length taken tangentially from a cold worked cannon has been cold worked by different amounts and such specimens, therefore, often break at a gauge mark, the marked reduction in elongation is neglected, and the final contraction of area and Charpy determine the safety of the cannon for service. A tensile Charpy value after cold working of 14 foot pounds is considered safe.

Dean Earle B. Norris (Lieut. Col. Ord. Reserve Corps) deduced from the cold working experimental data that for the bore enlargement generally used the modulus of elasticity after cold working was slightly greater than 20 million pounds per sq. in. The modulus after cold working and annealing at 300°C. is about 26 million and after cold working and annealing at 400°C. is about 28 million.

The low modulus of elasticity and the high elastic limit of a relatively thin wall cylinder that has been cold worked enables a liner to be used in high velocity cannon that can be removed and be easily replaced in the field when eroded so it is no longer accurate.

For cold working cannon for the army, pressures from 44,000 to 120,000 pounds per square inch are used. A pressure of 143,000 pounds per square inch has been used for experimental purposes.

Formerly, cannon were made by shrinking one layer on another until the required strength was secured. This method required each layer to be forged from an ingot, heat treated, bored and turned accurately and assembled by shrinkage. Cold working enables a cannon of equal strength and of less weight to be made of a single forging, and therefore in much less time and at less cost. Furthermore, cold working subjects each gun to a far severer test than heretofore possible, since the pressure applied to produce the desired permenent enlargement of the bore is from 2 to 3 times the service pressure.

Equipment has been developed that enables cannon to be cold worked on a quantity production basis. All cannon for the Army are made by this process.

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THE BIOLOGICAL SIGNIFICANCE OF ALUMINUM*

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Aluminum is the most widely and most abundantly distributed metallic element in the earth's crust, of which it represents 7.3 per cent. It is a major constituent of all kinds of soils and is invariably present in atmospheric dust and all materials which have been exposed directly to the elements. It is sometimes even present, though perhaps only in traces, in such highly purified products as "chemically pure" reagents. Accordingly, all living matter, both plant and animal, has always been intimately associated with aluminum compounds. This can be said not only of plants whose roots are set in soils and of animals, like the pig and the chicken, who root or scratch the ground, but also of human beings who live under the most artificial and refined conditions. Logically, therefore, biological chemists and students of nutrition have directed much effort toward ascertaining the possible rôle of aluminum in plant and animal physiology. As a result there is now a voluminous literature on the subject, but unfortunately, this literature is characterized by contradictory conclusions rather than definitely established facts. In this brief article it is impossible to review this literature. However, an attempt will be made to present a résumé of the prevailing and outstanding views on the physiological rôle of aluminum compounds, together with a few plausible explanations for some of the differences of these views.

According to some of the earlier reviews, like that of Langworthy and Austen,[1] published in 1904, the early work on the physiological rôle of aluminum compounds seems to have been

* Received for publication January 1, 1930.

[1] Langworth and Austen: New York, 1904.

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confined very largely, if not entirely, to determinations of the aluminum contents of biological products. According to all of the determinations quoted by Langworthy and Austen, aluminum is present in practically all kinds of biological products, sometimes in surprisingly high concentrations. Perhaps the most interesting and instructive feature of these and other similar analytical data on the aluminum content of biological materials is that a compilation of these analyses for any one substance when arranged chronologically shows that progressively less and less aluminum was found. Table 1 is such an arrangement.

This table shows that as the years have passed analysts have found in biological products progressively lower concentrations

TABLE 1

PARTS OF ALUMINUM PER MILLION

WORKER	DATE	EGG WHITE	WHEAT	CORN	POTATOES
Theile, R.	1867	762.0			
Penney, M. D.	1879		6000–25,000		
Myers, V. C., and Voegtlin, C.	1914		450	1700–1800	290
Gray, P. R.	1924	0.2–0.4	7.4–5.9	9.7–11.2	3.3
Sullivan, B., and Near, C.	1927		3.0		
McCollum, E. V., and Rask, O. S., and Becker, J. E.	1928	less than 0.5			
Underhill et al.	1929	0.17		2.6	9.7

of aluminum. Naturally, such a progression suggests that the high aluminum contents reported years ago was a matter of crude and unimproved analytical technics and that the lower concentrations reported in recent years is a matter of improved analytical technics. Accordingly, one is inclined to question whether the end or limit of the above progression has as yet been reached or whether the ultimate limit is one showing a complete absence of aluminum in biological matter. The writers are not at present prepared to answer this question. However, they do feel that chemical methods now used have not been demonstrated to be fault-free.

In these methods the analytical material is exposed to the laboratory atmosphere for long periods, usually more than twenty-

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four hours, during which there is great liability of introducing into the analytical sample aluminum from atmospheric dust. These methods, furthermore, involve the use of several reagents which are, of course, added to the sample. Every one of these reagents may contain significant amounts of aluminum, since the writers have found by means of the spectrographic method, which requires no reagents, that "chemically pure" and "analyzed" reagents frequently contain traces of aluminum. Finally, the method may not be absolutely specific for aluminum. In these methods the aluminum content is estimated by the color of an aluminum lake produced by either aurin or alizarin. However, the colors of these dyes are affected by hydrogen ion concentration, by iron and probably also by other substances. Accordingly, it seems reasonably probable that the color ultimately measured may be due in part to aluminum from outside sources or in part to other factors such as hydrogen ion concentration, etc., as well as to aluminum present in the sample. None of these objections can be raised against the spectrographic method. It consists of a rapid ashing of the sample followed directly by the spectrographic examination without the use of any reagents. The ashing need not be complete so that an incineration requiring only thirty minutes is usually sufficient. Finally, there is no question about the specificity of the spectrographic method unless mistakes are committed, as did Kahlenberg and Closs,[2] in confusing calcium lines for aluminum lines. Using the spectrographic method as outlined above, workers[3] in this laboratory have so far been unable to obtain conclusive evidence of the presence of aluminum in any biological matter, although as yet these workers are not prepared to say that aluminum is entirely absent. However, they feel reasonably certain that the aluminum concentration in biological materials, with two or three exceptions, is lower than 0.5 p.p.m. These exceptions are animal furs, lung tissue and intestinal walls, all of which obviously come in direct contact with aluminum-containing materials.

The absorption of aluminum out of the intestinal tract, and

[2] Kahlenberg and Closs: *Jour. Biol. Chem.*, p. 261, vol. 83, 1929.

[3] McCollum, Rask and Becker: *Jour. Biol. Chem.*, p. 753, vol. 77, 1928.

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its deposition in the liver, kidneys, spleen, etc., and its functions in those organs, if absorbed, are other pertinent questions bearing on the biological significance of aluminum. The answers to these questions as found in the literature at the present time seem again to depend to a great extent on the method employed for determining aluminum. Myers, et al., and Underhill, et al., both using colorimetric methods for determining aluminum, have concluded that aluminum present in the diet is absorbed and deposited in the above and other organs. Myers, et al.,[4] report from 0.3 to 2 p.p.m. of aluminum in the several organs of aluminum fed rats, whereas Underhill, et al.,[5] from 6 to 100 p.p.m. of aluminum in the several organs of starving and "control" dogs. The reader can draw his own conclusions concerning the reliability of such results. To say the least, both cannot be correct, even though their results were obtained on different animals. In this laboratory rats have been fed diets containing 600 p.p.m. of aluminum in the form of aluminum chloride and also in the form of a sodium aluminum sulphate phosphate baking powder. None of the organs of these rats were found to contain aluminum in a sufficiently high concentration to be detected by the spectrograph. Our data, therefore, indicate that there is no appreciable deposition of aluminum in any of the vital organs of the rat even after the feeding of diets containing 600 p.p.m. aluminum.

Experimental evidence that aluminum possesses any vital function is very meager. Osborne and Mendel,[6] and Daniels and Hutton,[7] respectively, have obtained results which suggest that aluminum is in some way connected with growth and reproduction. To these one may add, if he so chooses, the analytical data showing the presence of aluminum in vital organs, and then assume that its presence there is not fortuitous. Spectrographic results obtained in this laboratory showing the absence of aluminum down to less than 0.5 p.p.m. suggest that aluminum possesses no vital function. So also do feeding experiments per-

[4] Myers et al.: *Jour. Biol. Chem.*, p. 595, vol. 78, 1928.
[5] Underhill, et al.: *Am. Jour. Phys.*, p. 1, vol. 90, 1929.
[6] Osborne and Mendel: *Jour. Biol. Chem.*, p. 311, vol. 15, 1913.
[7] Daniels and Hutton: *Jour. Biol. Chem.*, p. 143, vol. 43, 1925.

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formed in this laboratory. These experiments consisted of feeding to rats through three successive generations on a diet so free from aluminum that none could be detected in it by means of the spectrograph. Rats fed on this diet were normal in every respect, such as growth, general well-being, and reproduction. However, it is possible that our supposedly aluminum-free diets contained 0.1 or 0.2 p.p.m. and that this concentration was sufficient to supply the bodily needs of this element. It is also possible that similar concentrations, viz., 0.1 to 0.2 p.p.m. are present in certain organs and in such concentrations perform vital functions. Considerable research is necessary to ascertain definitely whether such concentrations of aluminum are essential to normal life. Spectrographic evidence that aluminum is not concentrated in any organ or tissue argues against the view that is plays any physiological rôle.

An extraordinary amount of consideration has been given to the possible toxicity of aluminum compounds. It has been the subject of legislation and litigation as well as experimental work, all of which has been admirably summarized by E. E. Smith[8] in his book, "Aluminum Compounds in Foods." For detailed and comprehensive information on this question the reader is referred to Smith's book. However, it may be said that the aluminum ion or radical is non-toxic. Recent investigators like Myers et al.,[4] Underhill et al.,[6] and the writers,[3] who disagree on other aspects of the biological rôle of aluminum compounds, are all agreed that aluminum compounds are not toxic or harmful to health in such concentrations as result in human diets from a normal or even liberal use of the sodium aluminum sulphate phosphate type of baking powder.

[8] Smith, E. E.: "Aluminum Compounds in Foods," Paul B. Hoeber, Inc., New York, 1928.

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A FACTOR IN THE TEMPERATURE OF THE STRATOSPHERE

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When we first heard, some thirty years ago, that the temperature of the air rather rapidly decreases with increase of height up to the level of the highest cirrus, or wispy, clouds, and from there on, as far as a balloon could carry a thermometer, remains practically constant, we just didn't believe it—not all of it. We accepted, of course, the first part of the statement to the effect that the greater the height the colder the air. We had gotten used to that from mountain climbing, and from the records kept by balloonists. Then too we had found a good physical reason why it should be so, or at any rate an essential part of that reason. It is this. Ascending air expands, because the pressure on it grows less and less by the weight of the air left below, but it expands against the weight of the air that still is above it, and therefore does work. Now, to do work it must expend energy, and its only available energy for this purpose is its heat. Evidently, then, ascending air, expanding as it goes, and doing work at the expense of its own heat, must get colder and colder with increase of height. All this is in perfect accord with our laboratory experiments, and so we accepted the fact of the decrease of temperature with increase of height as a phenomenon which, if not entirely self-evident, at least is so easy to explain as scarcely to merit a passing thought.

That is where we made at least two mistakes. In the first place, even when it does occur it isn't half so easy to explain as we thought it was, and, in the second place, it doesn't occur at all in the high atmosphere. Of course the pressure continuously decreases with gain of level beyond the highest clouds, just as

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it does below them, and so asking us to believe that the temperature does not also decrease up there with increase of level just as it does in the cloud region was asking too much; it was contrary to our laboratory experience. However, after hundreds of records obtained by sounding balloons (small balloons carrying only registering instruments) had shown that immediately the uppermost cloud level is passed the temperature really is practically constant, why of course we had to accept it as a fact, and revise our explanations accordingly.

In the end it all came out simply enough. Our previous reasoning had been perfectly correct, but the premises were sadly deficient. We had left out of account the effects of radiation, and had set no limit to convection. Throughout all that portion of the atmosphere in which clouds of any kind occur, that is, from the surface up to the height of 6 to 7 miles, in middle latitudes, and 8 to 10 miles in tropical regions, there is decided convection—change in level of individual masses of air. The temperature, therefore, of each such mass does vary with height, and as the whole of this portion of the atmosphere is involved in this continuous vertical turn-over so also does this temperature relation extend to its every portion. But beyond the clouds vertical convection, if it exists at all, is so slow as to be practically absent so far as temperature effects are concerned. Here no one portion of the air changes temperature with altitude for the good and sufficient reason that it neither rises nor falls. Heat is not added to it by compression, nor taken from it by expansion. It therefore comes to that particular temperature at which it can lose heat by radiation at exactly the same rate that it gains heat by absorption. From this level up the intensity of the radiation from the earth and atmosphere below is practically independent of height. That is why temperature up there also is independent of height. It doesn't change appreciably even from day to night, and so we infer that it is not much affected by sunshine directly.

Thus again we had come to that state of mental ease that goeth with understanding. But the ease was of short duration. It soon was found that the upper air, the stratosphere, as scientists now call it, is coldest over equatorial regions and becomes gradu-

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ually warmer with increase of latitude, the extreme difference being around 35° Fahrenheit—coldest over the warmest earth and warmest over the coldest earth. Here was a poser, and we are not through trying to explain it yet. And now they (certain scientists) tell us that up beyond the highest reach of our balloons there is ozone in the very thin air. Well, that is what we would expect from the fact that ozone is produced whenever a certain portion of ultraviolet radiation falls on oxygen. But botheration again! There seems to be least ozone over tropical regions, where we would expect most, and more and more with increase of distance from the equator, and not less and less. Well, this isn't explained yet either, but we can make use of it, and that is what we propose now to do.

Ozone is a powerful absorber of the long wave-length radiation that goes out from the earth and its water-soaked atmosphere. Furthermore, whatever quantity of radiation the ozone absorbs, that same quantity, changed in part to other wave-lengths, it must reradiate, otherwise it clearly would do what obviously it is not doing, that is, continuously get either warmer or colder. Now, as the radiation by the ozone evidently is as much in one direction as another half of it is back towards the lower atmosphere. It also is evident that where there is least ozone the percentage of absorption and reradiation also is least, and as the quantity of the ozone increases so also does this percentage of return radiation. In short, one reason (not the only one) why the stratosphere becomes colder and colder as we go from high latitudes to the equator, is because the ozone blanket at the same time grows thinner. It is a little like sleeping warmly outdoors under a quilt or shivering under a sheet—lots depends on the kind and quantity of the covering one has.

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THE CAUSE OF ERRORS IN GONIOMETRY WHEN BEARINGS OF RELATIVELY CLOSE LOOP TRANSMITTERS ARE BEING ASCERTAINED*

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1. Some years ago the writer carried on tests in connection with the development of the now well known equisignal beacon transmitter with a view to improving the directional accuracy by also furnishing the aircraft with directional receivers, as this would make deviations from the correct course more readily noticeable.[1] Unfortunately it was found, however, that as the aircraft approached the beacon, slight deviations caused confusing results which were then further investigated and found to be caused by induction fields usually neglected but which had serious effects at distances as great as six miles. Since that time similar tests have been made with 71 meter instead of 1000 meter waves, in order to be within visual sight of the testing stations. The results were identical with those previously obtained and bearing errors up to 90 degrees were found.

2. In the following will be given a brief explanation of the cause of these errors and the difficulty sometimes experienced in obtaining any bearings whatsoever. Finally, there will be given the results of one series of calculations and the results obtained by field measurement.

3. It is well known that the magnetic field due to a single vertical wire is

* Communicated by Major General George E. Gibbs, Chief Signal Officer, U. S. A. Received for publication December 17, 1929.

[1] Reference to article on "Space Characteristics of Antennae" by the author, appearing in February, 1927, issue *Jour. Franklin Inst.*, p. 296, formula XI, for two vertical loops and formula XVII for a vertical loop and inclined airplane antenna.

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$$H_t = -\frac{h\,\omega\,I_o}{10\,cd}\cos\omega\left(t-\frac{d}{c}\right)-\frac{h\,I_o}{10\,d^2}\sin\omega\left(t-\frac{d}{c}\right)$$

where h (the height of the wire), and d (the distance) are given in centimeters, c is 3×10^{10} cm. per second (the velocity of light), I_o the peak current in amperes, and H_t the peak induction field in Gilberts per cubic centimeter.[2] The first part of the right side of the equation is the radiation component, the second part, the induction component. Applying this data to a loop transmitter of height h and width l, in centimeters, we at once find that along the plane of the loop the radiation field from the loop is due to the fields of the two vertical wires in which currents 180 degrees out of space phase are flowing. Designating the radiation field by H_r the two components add algebraically to give

$$H_r = -\frac{h\,\omega\,I_o}{10\,cd}\cos\omega\left(t-\frac{d}{c}\right)+\frac{h\,\omega\,I_o}{10\,c(d-l)}\cos\omega\left(t-\frac{d-l}{c}\right) \qquad (1)$$

If d is large compared with l we can write the equation as follows:

$$H_r = -\frac{h\,\omega\,I_o}{10\,cd}\left[\cos\omega\left(t-\frac{d}{c}\right)-\cos\omega\left(t-\frac{d-l}{c}\right)\right] \qquad (2)$$

The quantity in square brackets, however, can be written

$$-2\sin\omega\left(t-\frac{d-l/2}{c}\right)\sin\frac{\omega\,l}{2\,c} \qquad (3)$$

The resultant effective value of this field is

$$2\,\frac{h\,\omega\,I}{10\,cd}\sin\frac{\omega\,l}{2\,c} \qquad (4)$$

and on substituting first $\omega l/2c$ for $\sin\omega l/2c$ and then $2\pi/\lambda$ for ω/c we obtain

$$H_r = \frac{4\,\pi^2\,h\,l\,I}{10\,\lambda^2\,d} \qquad (5)$$

for the effective field, I being the effective current.

[2] Bur. Stand. Bull. 354, p. 441.

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4. If we now consider the induction field H_i due to both sides of the loop we obtain in a similar manner:

$$H_i = -\frac{h\,I_o}{10\,d^2}\sin\omega\left(t-\frac{d}{c}\right)+\frac{h\,I_o}{10\,(d-l)^2}\sin\omega\left(t-\frac{d-l}{c}\right) \tag{6}$$

here again we can, if d is considerably greater than l, write

$$H_i = -\frac{h\,I_o}{10\,d^2}\left[\sin\omega\left(t-\frac{d}{c}\right)-\sin\omega\left(t-\frac{d-l}{c}\right)\right] \tag{7}$$

The quantity in square brackets simplifies to

$$2\cos\omega\left(t-\frac{d-l/2}{c}\right)\sin-\frac{\omega\,l}{2\,c} \tag{8}$$

and the resultant effective value of the induction field becomes

$$\frac{2\,h\,I}{10\,d^2}\sin\frac{\omega\,l}{2\,c} \tag{9}$$

Making the same substitutions as in the previous case we now obtain

$$H_i = \frac{2\,\pi\,h\,l\,I}{10\,\lambda\,d^2} \tag{10}$$

5. To determine the distance at which the two fields are of equal intensity along the plane of the transmitter loop we equate (5) and (10) and find that $d = \lambda/2\pi$ as in the case of a simple antenna; this distance is desired as it will simplify the calculation to be made below.

6. At this specific distance and in the plane of the loop both fields are equal. They are also both horizontal and at right angles to the direction of propagation, or line of sight. Their instantaneous values are however:

$$H_r = -\frac{4\,\pi^2\,h\,I_o\,l}{10\,\lambda^2\,d}\sin\omega\left(t-\frac{d-l/2}{c}\right) \tag{11}$$

and

$$H_i = \frac{2\,\pi\,h\,I_o\,l}{10\,\lambda\,d^2}\cos\omega\left(t-\frac{d-l/2}{c}\right) \tag{12}$$

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these two equations simplify at the critical distance $d = \lambda/2\pi$ to the following:

$$H_r = -\frac{h\,l\,I_o}{10\,d^3}\sin\omega\,k \tag{13}$$

and

$$H_i = \frac{h\,l\,I_o}{10\,d^3}\sin(\omega k + \pi/2) \tag{14}$$

where k is written for

$$t - \frac{d - l/2}{c}$$

as a simplification. From (13) and (14) we see at once that the radiation field is 90 degrees in advance of the induction field. So far as a direction finder is concerned an accurate bearing can, therefore, be obtained if it is set up in the plane of the transmitting loop.

7. If we now examine the radiation and induction fields at a point at right angles to the plane of the transmitter but at the same distance as before, we find that the radiation field is now zero as its intensity varies as the cosine of the angle θ measured from the plane of the transmitting loop. The field intensity is, therefore,

$$H_r = -\frac{h\,l\,I_o}{10\,d^3}\sin\omega\,t\cos\theta \tag{15}$$

or in this case zero. So far as the induction field is concerned at the new location it is not at all zero but

$$H_i = \frac{h\,l\,I_o}{10\,d^3}\cos\omega\,t\,(1 + 3\sin 2\,\theta)^{\frac{1}{2}} \tag{16}$$

consequently in this case it simplifies to

$$H_i = \frac{2\,h\,l\,I_o}{10\,d^3}\cos\omega\,t \tag{17}$$

The radiation field has in other words decreased to zero while the induction field had doubled in value.

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8. It is important now to consider the plane of polarization of the two fields; the radiation field H_r is well known to be always polarized at right angles to the direction of propagation and to be horizontal for propagation along the ground. The induction field, however, takes up entirely different position angles depending on the angle θ. If we examine $(1 + 3 \sin^2 \theta)^{\frac{1}{2}}$ we find that it can be

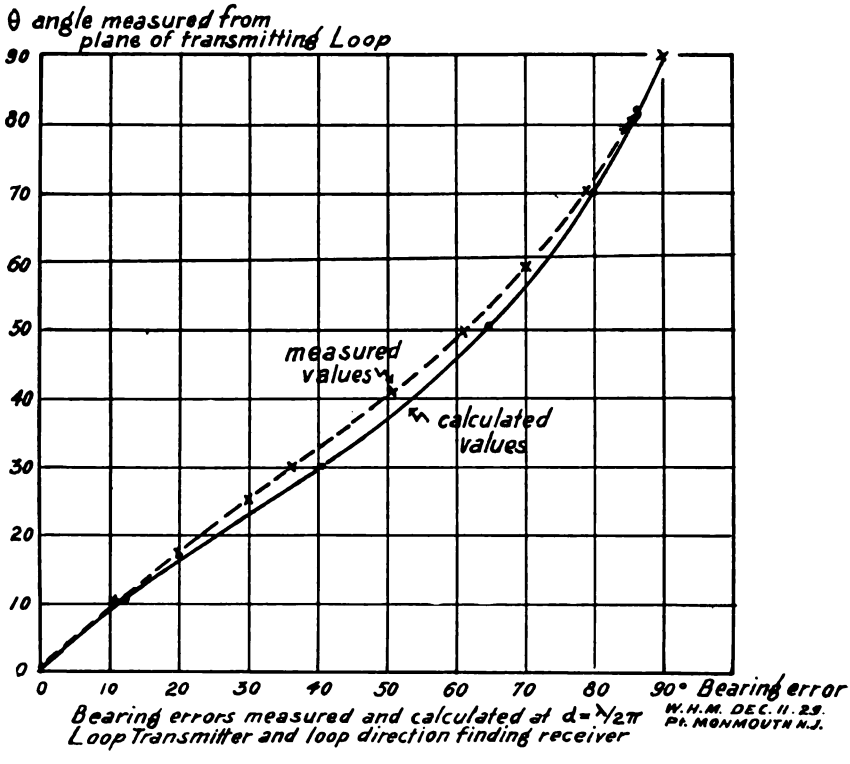

FIG. 1

resolved into two space components at right angles to one another; namely, cos θ and $2j \sin \theta$ the former being horizontal and perpendicular to the line of sight, the latter horizontal and along the line of sight. We see, therefore, that the induction field, when θ is 90 degrees, lies entirely along the line of sight and consequently a receiving loop must be parallel to the transmitting loop in order to be cut by the strongest fields. The bearing obtained in the

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normal manner is obviously 90 degrees in error; it is, however, very sharp as no other field components exist.

9. It is most interesting to consider the fields between the previous limits of θ. Obviously, if the induction and radiation fields were in time phase, sharp minima or zero readings would be obtainable although they would naturally give incorrect bearings. We have found, however, that the fields are 90 degrees out of time phase and a little thought will make it clear that elliptically polarized fields will be caused which will make it impossible to obtain zero readings and increasingly difficult to obtain minima as we depart from the limiting conditions.

10. Let us examine the fields at the critical distance and at the angle $\theta = 30$ degrees. The radiation field is

$$H_r = -\frac{h\, l\, I_o}{10\, d^3} \sin \omega\, t \cos \theta \qquad (18)$$

let us call the fraction unity then the maximum radiation field will be cos θ or 0.866. Similarly the maximum induction field can be written $(1 + 3 \sin^2 \theta)^{\frac{1}{2}}$ or 1.325. This field consists of two components, as stated before; one of intensity cos θ or 0.866 in space phase but time quadrature with the radiation field, the second of intensity 2 sin θ or 1.0 in time phase but in space quadrature with the first induction component. The space phase angle between the radiation and induction fields is ϕ which is $\tan^{-1} 2 \tan \theta$ or in this case 53 degrees. The radiation field is consequently 90 degrees out of time phase and 53 degrees out of space phase with the induction field, thus producing an elliptically polarized field which at no time has a zero value. The semi-axes of this elliptical field can be calculated from formulae

$$a'^2 + b'^2 = a^2 + b^2 \text{ and } a'\, b' \sin \Phi = ab$$

where a' is the peak radiation field and b' the peak induction field, and Φ the space angle between the two. The major semi-axis is approximately 1.45, the minor semi-axis about 0.63, while the space angle of the major axis with respect to the radiation field is about 41 degrees. If a bearing is obtained at all it is, therefore, in error by 41 degrees.

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11. From similar calculations at the critical distance the following data may be taken as an example:

Actual field measurements are given in the last column.

θ	H_r	$H_i(\parallel H_r)$	$H_i(\perp H_r)$	H_i	Φ	BEARING ERROR	MEASURED ERROR
degrees							*degrees*
0	1	1	0	1.0	0	0°	0
10	0.985	0.985	0.347	1.045	19°30′	11°	11
30	0.866	0.866	1.000	1.325	53°	41°	36
50	0.643	0.643	1.532	1.662	67°14′	64°30′	61
70	0.342	0.342	1.879	1.91	79°42′	79°30′	79
90	0	0	2.0	2.0	90°	90°	90

From 30 to 80 degrees the bearings are difficult to obtain accurately at the critical distance. This and the fact that l is not necessarily negligible with respect to d will explain discrepancies between the last two columns of the table. Even at distances as great as 4 λ difficulty is observed in obtaining sharp minima between 70 and 87 degrees.

12. The above will give an idea of the difficulties which may be expected in locating large or small loop transmitters unless they are at distances greater than five or six wavelengths.

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EXCERPT FROM VOLUME I OF TRANSACTIONS OF THE MARYLAND ACADEMY OF SCIENCE AND LITERATURE, BALTIMORE, 1837

The first successful efforts to organize an association in Baltimore, for the promotion of science and literature were made in the year 1822. Similar associations had been previously contemplated; some had actually gone into operation, but they soon disappeared after an ephemeral existence. The Maryland Academy of Science and Literature was opened under more favourable auspices. A greater number of persons presented themselves willing to advance by their zeal the objects and the pursuits embraced within the scheme; so that, at already an early stage of its organization, by the spontaneous liberality of some of its members and of other gentlemen, the academy found itself in possession of an extensive collection of minerals, and an herbarium, the nucleus of a cabinet around which new materials might daily accumulate, and without which no association of like character can expect to hold together, nor can in truth be said to have an existence.

A strong appeal was then addressed to gentlemen of the learned professions in the city, and throughout the state, which was in some measure responded to, and the number of contributing members became soon sufficiently large, to justify the step of procuring an apartment, where the meetings of the Academy could be held; furnishing, at the same time a place of safe-keeping for the collection, which was beginning to acquire both extent and interest. Still there remained many difficulties to contend against. The limited pecuniary means at command, forbade the erection, or purchase, of a suitable edifice to be appropriated exclusively to the uses of the Academy. No building of a public nature could accommodate it; and the frequent removals thus occasioned, besides doing much damage to the collection, took away from it that character of permanency, alone capable of

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rendering it an object of solicitude to the members. At length, however, the collection was removed to a spacious hall, in a public edifice, eligibly situated, where in a short time it increased so as to become worthy the attention of the naturalist.

The principal accession which the property of the academy received at this period, consisted of a library, composed of standard works of reference, procured in part with a sum of money being the accumulated fund of a pre-existing society, which was thus transferred by its surviving members. The Academy stands indebted for this valuable acquisition to its then president, Robert Gilmor, Esq. who contributed besides, individually, by the donation of several costly and useful works. Other presents were also received from various quarters, the whole forming a collection of about eight hundred volumes, of the best publications in the different branches of the natural sciences. In the meanwhile, there was added to the cabinet an extensive series of geological specimens obtained from Germany, together with samples of the mineral formations occurring in this state. And subsequently, a considerable number of shells, recent and fossil, with numerous preserved individuals belonging to other departments of natural history, had been procured, all of which, whilst it gave evidence of zeal on the part of the few active members belonging to the academy, had become an object of interest to the scientific traveller, and proved that the natural sciences were not altogether neglected in Maryland. But in an unfortunate hour nearly the whole of this valuable property was consumed by fire.

Not discouraged by this calamity, the members of the Academy, acting under the authority of a charter obtained in the year 1826, have determined to re-organize their society. Fully persuaded of the intrinsic importance of their scheme, its utility, the character it may confer upon the city, as well as the general benefit that may accrue to the community by a co-operation of efforts to promote its accomplishment, they have set to work earnestly, not only to restore the Academy to what it was after twelve years of existence, but to re-establish it upon a basis of permanent prosperity. It is with infinite pleasure, therefore,

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that they find it in their power to announce, that in the short space of one year since its revival, having obtained a commodious set of apartments comprising one of large dimensions, the number of their collaborators having also greatly increased, their library already equals in extent, and surpasses in interest, that which they have lost, whilst the cabinet contains several thousand zoological, botanical, and mineralogical specimens. Every week brings new accessions to both; so that, at this time the rooms of the Academy afford to the student of nature a place of resort, where he may pursue his favourite study with gratification as well as improvement.

It is not the intention of the Academy, however, to confine its operations solely to the collection of natural objects. The members desire to extend its sphere of usefulness; by submitting to the learned their intellectual labours, that have heretofore been compelled to seek a channel of publicity through scientific journals at a distance. It is now proposed to publish from time to time, a volume, or part of a volume of Transactions, which will embody detailed accounts of the peculiarities in the natural history of Maryland, new investigations in the physical sciences, and original essays on subjects of general interest connected with them. An additional incentive to exertions will in this way be offered to the members; and, it is hoped, that the learned world will consent to accept the offering as an earnest of what is contemplated to be performed.

To regulate as well as to facilitate the operations of the Academy the members have arranged themselves into sections, to which all donations according to their kind are referred, and are reported upon at the time, or at a succeeding meeting, by the chairman, or any other member to whom the subject may by him have been committed. The sections are denominated as follows:

Section 1.—Mathematics, Astronomy, and Physics, embracing Natural Philosophy and Mechanics.—Chairman, L. BRANTZ.

Section 2.—Chemistry.—Chairman, J. T. DUCATEL.

Section 3.—Mineralogy and Geology, including Physical Geography, and the history and classification of Fossil remains.—Chairman, P. T. TYSON.

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Section 4.—Zoology, embracing the comparative anatomy and physiology of animals—and further divided into six classes, viz: on the history and classification of Mammalia—Birds—Reptiles—Fishes—Insects, and Mollusca.—Chairman, R. E. GRIFFITH.

Section 5.—Botany, including Vegetable Physiology.—Chairman, W. E. A. AIKIN.

In this state of things, a renewed appeal is confidently made to the American public, to similar institutions in this and other countries, and to the lovers of nature all over the world, to aid in furthering the objects of the Academy by contributing whatever they may have to spare in books, specimens of natural history, and other objects of interest. As announced in a previous circular, 'the collections which the academy seeks to make, embrace all that can claim the attention of the literary and scientific. They include minerals, shells, fossils, specimens in natural science, books, coins, aboriginal antiquities, maps and documents illustrative of the history, geography, or literature of any portion of the world, and in particular of Maryland. Unpublished barometrical or thermometrical observations—descriptions of celestial or terrestrial phenomena and state statistics which have never been given to the world, are likewise among the means of information which it seeks to gather and make useful.' The academy addresses itself especially to its corresponding members, soliciting their aid in furnishing matter for the pages of its Transactions, to the accurate publication of which the most scrupulous attention will be given.

Subjoined is a list of the present officers, and of the resident, honorary and corresponding members of the academy.

OFFICERS ELECTED JANUARY, 1837.

President,
JULIUS T. DUCATEL.

Vice-Presidents,
PHILIP T. TYSON,
R. EGLESFELD GRIFFITH.

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Secretary,
WILLIAM R. FISHER.

Treasurer,
DAVID KEENER.

Librarian,
J. H. QUINBY.

Curators,
JAMES GREEN,
J. H. ALEXANDER,
WM. EDWD. COALE,
WM. RILEY.

RESIDENT MEMBERS.

Names	When elected
P. Macaulay,	1821.—May 10.
J. T. Ducatel,	do.
Geo. Frick,	do.
Joshua I. Cohen,	1822.—June 1.
R. Gilmor,	November 2.
David Keener,	December 7.
Philip T. Tyson,	do.
Edw'd Dennison,	1823.—December 2.
I. Tyson, Jr.	1824.—February 24.
J. Pennington,	April 20.
George S. Gibson,	September 30.
Charles F. Mayer,	1826.—January 19.
Jos. W. Patterson,	February 2.
Geo. S. Sproston,	do.
Wm. Gwynn,	do.
Rich'd S. Steuart,	February 16.
J. I. Cohen, Jr.	do.
Charles Tiernan,	March 2.
T. Edmondson, Jr.	1828.—November 27.
Geo. H. Calvert,	1829.—August 4.
Geo. W. Andrews,	1830.—January 21.
H. Willis Baxley,	1832.—January 12.
A. B. Cleveland,	November 1.
J. H. Alexander,	1833.—March 28.
John P. Kennedy,	September 12.
J. H. B. Latrobe,	do.
J. Mason Campbell,	November 28.
Rev. Hector Humphreys, D.D.	do.
Wm. N. Baker,	1834.—September 12.
Wm. R. Fisher,	1835.—February 12.

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Names	When elected
Benjn. H. Latrobe,	April 16.
John R. W. Dunbar,	1836.—January 1.
Wm. E. A. Aikin,	do.
Lewis Brantz,	January 28.
Theodore Jenkins,	do.
James Green,	do.
Rich'd Wilmot Hall,	February 11.
Nathan R. Smith,	do.
John R. Hazlehurst,	do.
John B. Fitzgerald,	February 18.
Isaac Trimble,	do.
J. H. Quinby,	do.
Rich'd Caton,	1836.—March 3.
John L. Webster,	do.
Wm. G. Thomas,	do.
Rev. John J. Chanche,	April 7.
Wm. Riley,	do.
Wm. Ed. Coale,	do.
Wm. Minifie,	do.
R. Eglesfeld Griffith,	November 3.
Cornelius McLean,	do.
John Fonerden,	do.
F. H. Davidge,	1837.—January 19.
F. Chatard,	do.
Rev. John G. Morris,	February 2.
Samuel Annan,	do.
Samuel G. Baker,	do.
Rev. Geo. W. Burnap,	February 9.
John Prentiss,	do.
Thomas Buckler,	do.
Ramsay McHenry,	March 16.
J. Hanson Thomas,	April 6.
Alex. C. Robinson,	do.
J. C. Richards,	do.
R. S. Harlan,	April 13.
P. Rogers Hoffman,	do.
Wm. Geo. Read,	May 10.
Charles Bell Gibson,	August 25.

CORRESPONDING MEMBERS.

Names	Residence
James E. Dekay, M. D.	New York.
John E. Holbrook, M. D.	Charleston, S. C.
Lardner Vanuxem,	Bristol, Pa.
Wm. H. Keating,	Philadelphia.
Gerard Troost, M. D.	Nashville.

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Names	Residence
Christopher Hughes, Esq.	
Charles L. Bonaparte, Prince of Musignano.	Rome.
Wm. Darlington, M. D.	West Chester, Pa.
Gen'l J. G. Swift,	New York.
Edmund Ravenel,	Charleston.
Elias Durand,	Philadelphia.
Lt. Col. S. H. Long,	U. S. Army.
Mifflin Coulter, M. D.	U. S. Navy.
Leonard Osborne, M. D.	U. S. Navy.
Edw'd H. Worral, M. D.	U. S. Army.
W. H. Davidson, M. D.	Winchester, Va.
I. Bruce, Esq.	do.
D. H. Barton, Esq.	do.
J. W. Greetham, M. D.	Mount Vernon, Ill.
J. Orville Taylor, Esq.	New York.
A. Sidney Doane, M. D.	do.
Amos Binney, M. D.	Boston.
Charles J. Latrobe, Esq.	England.
Mendes I. Cohen, Esq.	
O. Hill, M. D.	Lewiston, N. Y.
Charles Short, Esq.	Lexington, Kentucky.
John L. Riddell, M. D.	Cincinnati, Ohio.
James E. Heath, Esq.	Richmond, Va.
Philip Williams, Jr. Esq.	Winchester, Va.
Charles B. Shaw, Esq.	Richmond, Va.
James Herron, Esq.	do.
Thomas Pennie, Esq.	Florida.
Z. Pitcher, M. D.	U. S. Army.
Charles Cramer, Esq.	New York.
Rev. John Backman,	Charleston, S. C.
G. W. Clinton, Esq.	Canandaigua, N. Y.
H. A. Schrœder, Esq.	Mobile.
W. L. Hawkins, M. D.	Annapolis.
Cons. I. I. de Macedo,	Lisbon, Portugal.
Prof. Jameson,	Quito, S. America.
L. R. Gibbs, M. D.	Charleston.
Rev. Virgil H. Barber,	Conowingo, Pa.
Matthew Carey, Esq.	Philadelphia.
James C. Palmer, M. D.	U. S. Navy
L. C. Gale, M. D.	New York.
H. P. Sartwell, M. D.	Pen Yan, N. Y.
B. D. Green, M. D.	Boston.
Copley Green, M. D.	do.
Harris, M. D.	do.
Charles Lukin, Esq.	Guayquil.
J. Romeyn Beck, M. D.	Albany.
M. Henry Webster.	do.
Wm. H. May, M. D.	Palmyra, N. Y.
J. Trowbridge, M. D.	Buffalo, N. Y.

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Names	Residence
James Sullivan, Esq.	Pembroke, N. Hampshire.
Prof. C. D. Cleveland,	Philadelphia.
Prof. James Hall,	Troy, N. Y.
Prof. E. Adams,	Dartmouth College.
Henry Prentiss, M. D.	Gloucester, Mass.
James Renwick, LL. D.	New York.
Lieut. M. G. L. Clairborne,	U. S. Navy.
Lieut. A. K. Long,	do.
S. T. Laurason, M. D.	do.
G. Von Dem Busch, M. D.	Bremen.
Signor Vitore Pecchioli	Pisa.
I. R. Jackson, Esq.	Philadelphia.
James B. Rogers, M. D.*	Cincinnati.
E. Geddings, M. D.*	Charleston.
B. M. Byrne, M. D.*	U. S. Army.
Robley Dunglison, M. D.*	Philadelphia.
T. Phillips Allen,*	North Carolina.
Frederick Hall,	Washington.
Thomas P. Jones,	do.
Dr. Hornbeck,	St. Thomas.
I. Pearson Smith,	South Carolina.
Willis Buel,	Zanesville.

HONORARY MEMBERS.

José Silvestre Rebello, Chargé d'affaires,	Brazil.
Right Rev. Bishop England,	Charleston, S. Carolina.
Thomas Cooper, M. D. LL. D.	Columbia, do.
Benj. Silliman, M. D. LL. D.	New Haven, Con.
William Maclure, Esq.	Philadelphia.
Peter S. Duponceau, Esq. LL. D.	do.
John K. Mitchell, M. D.	do.
J. N. Nicolet,	Royal Observatory, Paris.
Baron de Roenné, Minister resident, of the king of Prussia,	Washington.
Don Ramon della Sagra,	Madrid, Spain.
F. R. Hassler,	Washington.
Sir N. Carlyle,	London.
Com. De Figanière, Chargé d'affaires of the Queen of Portugal,	Baltimore.
John J. Audubon,	

* Formerly resident members.

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SECTIONS

NOTE FROM THE BOTANICAL SECTION

Cassia medsgeri Shafer in Maryland

This comparatively recent segregate from *Cassia marilandica* L. was found last September in Baltimore County, just a few miles north of the city boundary. It was in fruit, and thus readily determined. Superficially, only, does it look somewhat like *C. marilandica*, but its strongly curved pods, at once, distinguish it; those of *marilandica* being only slightly curved. Closer study and one notes that whereas the pods are flat in *marilandica*, in *Medsgeri* they are rather thick, and further, that the segments of the pod in *marilandica* are as long as broad, but in *Medsgeri* they are much shorter than broad; and that the seeds in *marilandica* are flat, in *Medsgeri*, they are rather thick. Another peculiarity of *Medsgeri* is that the gland found in *marilandica* generally well down in the axile of the leaf, is here found frequently about an inch from the axile. The colony of plants found, were growing in rather heavy soil, and in an open glade. —CHARLES C. PLITT, Ph.G., Sc.D., Professor of Botany and Pharmacognosy, School of Pharmacy, University of Maryland.

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CANCER RESEARCH LABORATORY

Three rooms in the basement of the southwest wing of the Academy building, directly under the main assembly room, have recently been renovated and converted into research rooms. These will prove to be well-suited for this purpose as the concrete floors and thick walls of brick and stone make them fire resistant and the ample window area assures adequate light and ventilation. Experience has already shown that the traffic on Charles Street will not interfere with the operation of delicate instruments mounted on the floor or walls.

New, modern lighting fixtures and wiring have been substituted for the old ones. Convenient outlets for gas and electricity have been provided and each electric outlet has an individual fuse and switch. Both the lighting and laboratory electric circuits are served by a new line connected directly to the powerline, thus avoiding any possibility of overloading old circuits in the building.

Equipment for the work which is at present chiefly concerned with the effect of temperature on cancer and normal tissues is being supplied as needed Two high-frequency electrical generators, supplied by the General Electric Company, are used in one method of changing the body temperature of diseased and normal rats. Electrical measuring instruments and special thermocouples for temperature measurements are available in the laboratory.

The smallest of the three rooms has been specially prepared to house the animals which are to be used in the experimental work. An adequate supply of rats of known heredity are available from the private laboratory of Dr. George Walker.

The research work on cancer which is now under way is a special phase of the investigation which Dr. Walker, a member of the medical section of the Academy, has been conducting for some time in his private laboratory. The Academy is coöperating in the work along those lines which require the use of facts

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from various fields of science. Dr. S. Karrer, Director of Research, Consolidated Gas, Electric Light and Power Company of Baltimore, assisted by Mr. G. B. Estabrook, is associated with Dr. Walker in this research. The work illustrates the kind of coöperation which the Academy will foster and in which it hopes to be especially useful as its facilities enlarge.

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ELECTIONS TO MEMBERSHIP

RESIDENT MEMBERS

Mr. Buddy Field, 5308 Gwynn Oak Avenue, Baltimore.
Mrs. Leon Ginsberg, 3514 Springdale Avenue, Baltimore.
Dr. S. Karrer, Research Laboratory, Consolidated Gas, Electric Light and Power Company, Baltimore.
Mr. Franklin Oertele, 5609 Wayne Avenue, Baltimore.
Miss Anne Shipley, 2629 Saint Paul Street, Baltimore.
Mr. C. M. Shipley, 2629 Saint Paul Street, Baltimore.
Dr. George Walker, 1 East Center Street, Baltimore.
Miss Elizabeth Pumphrey.
General George O. Squier.

LIFE MEMBER

Miss Addie Penn, Sykesville, Maryland.

Changes of address are requested.

NECROLOGY

Elmore B. Jeffry.
Peter Nostrand.
Theodore Wells Pietsch.
Dr. Harris B. Rogers.
Sewell S. Watts, Sr.
Dr. Charles Wolfe.

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THE STRUCTURE OF THE ATMOSPHERE AND AVIATION*

W. J. HUMPHREYS, C.E.; PH.D.

Professor of Meteorological Physics, United States Weather Bureau

"When I was a boy" may not have the pedagogue's approval for the opening phrase in a scientific article, but I shall use it anyhow, for I want to say that when I was a boy no title, unless used by a Jules Verne, could have been more absurd than both ends of the one here chosen. Up to that time only Icarus and Darius Green had essayed the "avis" mode of travel, and it was never claimed, even in patent suits, that either was a worthy pioneer in the practice of any desirable feature of the art. And anyone then writing on the structure of the atmosphere would have done so after the manner of the chapter on snakes in Horrebow's "Natural History of Iceland." "In all the island there are no snakes." Now, however, we already know of various ways in which the air is streaked, laminated and otherwise divided into distinct portions, and presumably there still are many more parts, according to this or that basis of division, that yet will be found and studied.

TROPOSPHERE AND STRATOSPHERE

At about the close of the last century soundings of the atmosphere were begun with the aid of small balloons carrying light devices that automatically registered the temperature and pressure throughout both the ascent and the descent—a kind of exploration that soon was taken up at various places. From these records, in turn, the heights corresponding to given points on the traces were readily computed. In this way we gradually have come to know the average temperature and pressure of the air at every height from the surface of the earth up to at least 12 to 15

*Received for publication March 21, 1930.

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miles, under different weather conditions, for all the seasons, and in many parts of the world. Pretty soon a means of registering the humidity was further added to the apparatus carried, so that we now have a fair knowledge also of the average vertical distribution of water vapor that corresponds to each particular type of weather. Obviously, too, these sounding balloons, as they are called, afford some knowledge of the direction and velocity of the wind at various levels for the particular time and place at which a flight is observed.

From the data thus obtained several interesting generalizations soon became evident. The most conspicuous of all, and for a long while the most doubted, because it was not understood, was the fact that at 6 or 7 miles above sea level, in middle latitudes, and generally 8 to 10 in tropical regions, the temperature no longer decreases with increase of height, but remains substantially constant. How far this equal temperature, or isothermal condition, extends is, of course, unknown, but it does go at least to the greatest altitudes yet attained, that is, 15 to 20 miles. It may extend to the limit of the atmosphere of appreciable density, or it may not. We have no direct and positive evidence of either alternative. This much we know. From the surface up to a considerable distance above sea level, generally 6 to 10 miles, depending mainly on the latitude, the temperature decreases at the average rate of about 1°F. in 300 feet. Then, almost abruptly, as a rule, the temperature practically ceases to change with further ascent. This unsuspected and striking phenomenon, then, divides the atmosphere into two great parts; a lower portion in which temperature rapidly decreases with increase of height, and an upper in which the temperature is nearly independent of height. In the lower portion convection, or ascent and descent of the air, can occur under certain conditions, because although ascending air cools by expansion (the pressure on it being decreased by the weight of the air left below) its ascent brings it into air that also is colder. Sometimes the ascending air, especially when saturated with water vapor, cools less rapidly with increase of height than does the air through which it is passing. In this case convection is certain and often vigorous. Similarly, a local

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mass of air, particularly when cloud-laden, may warm less rapidly on sinking, as such masses do just after sundown, than the air it is falling through, whereupon convection again is inevitable. In short, this lower, cooling-with-altitude portion of the atmosphere is a region of convections and overturnings—not at all times, but under humidity conditions that will be explained later. It therefore has been called the *troposphere*, the sphere, or spherical shell, in which turning (going up and going down), or convection, occurs.

In the region above the troposphere, where the temperature is constant with height, marked or vigorous convection does not and cannot occur. It cannot occur here because rising air rapidly cools with ascent, owing to expansion incident to decrease of pressure on it by the weight of the air passed through. Such cooling would keep the rising air all the time colder and therefore heavier, volume for volume, than the surrounding air and thereby quickly reduce its motion first to zero and then reverse it. Formerly this was called the isothermal region, and to some extent it is still so called, owing to the fact that vertically, so far as explored, the temperature is substantially constant. Since convection here is impossible masses of air forced into this region would spread out in horizontal strata, and indeed there commonly are evidences of the existence of just such strata, though we seldom if ever are sure of their origin. This finer structure suggested the other, and now the all but exclusive, name, "stratosphere," of this region. Thus the troposphere and the stratosphere are quite distinct from each other. Clouds and every sort of precipitation, rain, snow, graupel, sleet and hail, and every kind of storm, forever agitate the former, but never for a moment disturb the serenity or overcome the stability of the later. They are sharply separated, the one from the other, along an approximately horizontal but invisible surface called the tropopause, and so called because that is where convection ceases, as above explained.

One frequently reads of the great advantage the aviator is going to have as soon as he can get up into smoothly flowing, two hundred to three hundred-miles-an-hour winds of the stratosphere. Or, rather, the advantage he is going to have when flying east, the direction these winds blow in middle latitudes. This sounds

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nice enough—perhaps that is the reason it is so often repeated—but it is only another case of the wish being father to the thought, for the winds in that cloudless realm are not so fast after all. This is shown in figure 1, copied from an article in the *Monthly Weather Review* of June, 1929, by Mr. L. T. Samuels, and giving the average velocities and directions of the wind at various heights at Groesbeck, Texas, during October, 1927, as determined with sounding balloons.

TRADES (TRADE WINDS)

When we examine the troposphere closely we find that it too has structure. Some of these parts are fleeting, but others are at least semi-permanent. One of the more nearly constant is the

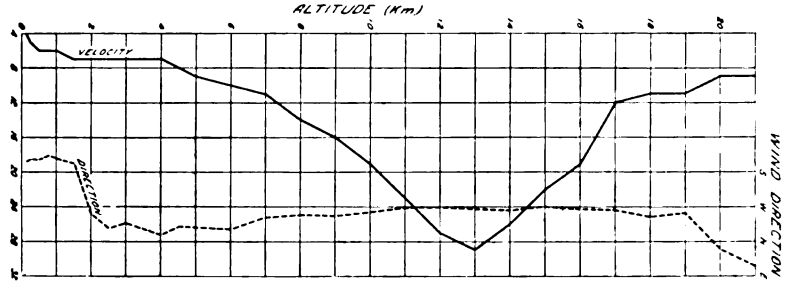

FIG. 1. MEAN WIND VELOCITY (METERS PER SECOND) AND DIRECTION CURVES, GROESBECK, TEXAS, OCTOBER, 1927

trade wind, or, better, the trade winds as there are several winds properly so designated. Advantage has been taken of them, of course, in shipping, especially by sailing vessels, but this is not the source of their name. It does not derive from any idea of commerce, but from the fact that their characteristic is persistent blowing along a particular "trade," that is, tread, track or way. The trades are east winds (winds from easterly points), over the tropical oceans, or, more exactly, between the latitudes 30°N., and 30°S. There really are five such winds that are well defined, one over the north Atlantic Ocean between latitude 30°N., roughly, and the Atlantic doldrums, or region of calms near the equator, and another over the south Atlantic between Latitude

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30°S., also roughly, and the same doldrums. Two other trade winds are similarly located over the Pacific Ocean, and one over the Indian Ocean, south of the equator, between Australia and Madagascar.

These wind currents, the trades, are very shallow near their poleward boundaries or edges, but grow gradually deeper and deeper to a maximum of at least 4 or 5 miles as their equatorial borders along the doldrums are approached. They are well defined and important structures of the troposphere.

ANTITRADES

Immediately over the trade winds are the antitrades, or winds that blow away from the equator and at the same time turn more and more nearly eastward and come down lower and lower with increase of latitude until they merge with, and become a part of, the prevailing westerlies—the winds beyond latitude 30°N. or 30°S., as the case may be, that from the surface up to at least well into the stratosphere usually are from westerly points. The antitrade (there is one over each trade wind) represents a part of the return to higher latitudes of its accompanying trade, which through most of its route approaches closer and closer to the equator. The rest of the trade, joined by a greater or less amount of tropical air, turns around the western end of a high pressure ridge, or ocean area of prevailingly light and variable winds and clear skies. The frequent and deep southerly winds onto the United States from the Gulf of Mexico and the Atlantic Ocean are of one of those great joint trade and tropical currents.

Here, then, are two major features or elements in the structure of the troposphere, the trade and the antitrade, the east wind and the west wind, that all who pilot the argosies of the skies must know, and know how to use to proper advantage.

And the troposphere has many other parts. Two of the strangest and most important of these, strange because though apparently impossible companions they yet are always together, are the cold wind and the warm wind that peacefully flow beside each other—that, in technical terms, are each in dynamical equilibrium with the other. We know that a column of warm air will not

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stand up in equilibrium with an adjacent column of cold air, and we know that we know it by the way cold out-doors air pushes up and away the warm air in a heated chimney or smoke stack. Hence we are unwilling at first to believe that a cold wind can blow alongside of a warm wind and not drive it away—that the twain can meet on equal terms and each hold its own. But they can and do, because an object, such as a mass of air, whenever moving over the earth tends always, because of the earth's rotation, to turn to one side or the other (the right, going with the wind, in the northern hemisphere, the left in the southern) of the course it is on. And the magnitude of this tendency (the force the moving object would exert on a frictionless vertical surface that would hold it to a fixed geographic direction) is proportional both to its mass and to its velocity. In the case, therefore, of adjacent stationary columns of warm and cold air only gravity is operative and the heavier (because colder), column underruns and buoys up the lighter. This is why air rushes up heated chimneys and smoke stacks—why they draw, and the higher the better. In the case of the winds, however, the situation is quite different, for in proportion to their mass and their velocity they now exert (or would, against a suitable restraining wall) a horizontal or deflective force that also must be considered. If, then, the winds were in the right direction, and had the proper positions with reference to each other, the colder from the east, say, and the warmer just south thereof and from the west, or, more generally, if they were passing each other counter clockwise (in the northern hemisphere, clockwise in the southern) they might have such velocities that the resulting deflective force would just balance the difference in pressure due to difference in density. Ordinarily this condition of equilibrium implies a very gently sloping interface between the warm current and the cold, with the former overrunning the latter. Owing, however, to surface friction and various obstacles, such as islands and mountains, to the free flow of the winds, and to a change for one reason or another, in the relative amounts of air on the two sides, perfect equilibrium never is long maintained. It does not break down abruptly and completely, but gives way quite slowly, and in so doing often leads to the

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development of the general cyclonic storm of the middle and higher latitudes.

COLD FRONT

When the break-down between the warm and the cold currents is well developed, with the mass of cold and, of course, polar air pushing its way equatorwards while the warmer air flows beside it poleward, we speak of the interface between them, or, rather, of the intersection of that interface with the surface of the earth, as a cold front. We also call this locus a windshift line because here the direction of the wind changes, as one system, the warm winds, departs and another, the cold, comes on. It likewise is called a squall line because all along it the winds are turbulent and squally and, in summer, often accompanied by thunder storms This cold front, then, is the boundary, along the surface, between distinct wind systems—between a system of relatively cold and dry winds under clear skies and from higher latitudes, and a system of comparatively warm and humid winds under clouded skies and from lower latitudes—two more of the great parts in the structure of the troposphere.

This wind-shift line, cold front or polar front (it has all these names and more besides) extending, as it commonly does, hundreds of miles from the center of a cyclone equatorward, cannot easily be flown around, and no wise pilot will cross it without due caution. Here the winds up to great heights are likely to be very turbulent, and here, too, violent thunderstorms can break almost without warning. Of course there are pilots who, like Tam O' Shanter, never mind the storm a "whistle"—but Tam was drunk! There is some danger from lightning—much more in the air, pierced by every discharge, than on the ground, reached by one in a hundred—and great danger from the winds if caught in the more violent portion of the malestrom.

WARM FRONT

The warmer of the two passing winds mentioned above soon reaches in the course of its poleward travel the colder air of higher latitudes. But here, as elsewhere, two masses of air, having

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different temperatures can not be in equilibrium with each other at rest and standing side by side. They must be, and are, in motion, and in such manner as to retain for a time, and to a greater or less extent, their individuality. Here again the colder air is wedged under the warm which flows not along this wedge, but up its slope—slantingly as a rule, but up, nevertheless. The line along which this part of the interface between the cold and the warm winds cuts the surface is called the warm front. Thus the cold and the warm sectors of the traveling cyclone maintain their independence as polar winds and tropical airs, respectively, until gradually separated from their sources, after which they soon are brought into like conditions each with the air of its new location and merged with it. In this way polar air becomes tropical air, and tropical winds polar winds, back and forth ceaselessly and indefinitely; but always as entities in their travels—as elements in the structure of the stratosphere—just as rivers and lakes are entities in the ceaseless round of water from oceans to continents and continents to oceans.

VELOCITY AND HEIGHT IN THE TROPOSPHERE

As is well known the speed of the wind varies at any level from time to time and place to place. It also, on the average, and away from warm and cold fronts, increases rapidly and undergoes considerable clockwise (in the northern hemisphere) turning with increase of height up to about 1500 feet above the surface, where very commonly *in the forenoon*, but not in the afternoon, it has a maximum value. Beyond this level the wind velocity generally decreases, *in the forenoon*, to a minimum at around 3000 feet when it becomes roughly constant up to 6000 to 10,000 feet above the surface, or whatever the current limit may be of the diurnal convection or mixing. Beyond this level, in turn, it commonly increases very nearly uniformly to another, and much greater, maximum a short distance below the base of the stratosphere, and then decreases with further increase of height to a small value at the level of 50,000 to 60,000 feet. At still greater heights the velocity once more increases, as indicated by theory and supported by observations on the drifting smoke of meteor trails. Most of

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these relations of wind velocity to altitude are shown in figures 1, and 2. The first representing 44 soundings made at Groesbeck,

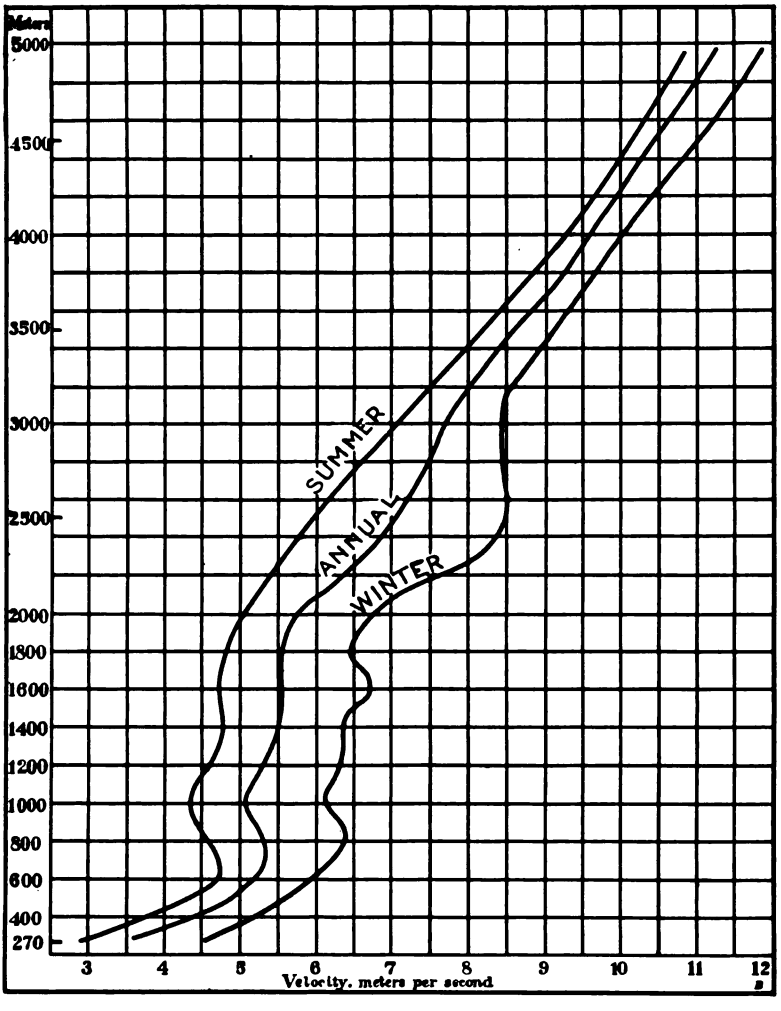

FIG. 2. WIND VELOCITY AND ELEVATION; AFTER FABEIS

Texas, in October, 1927, about three-fourths of them in the afternoon; the second, some 200 forenoon soundings made near Rome,

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Italy, through the year June 1910—May 1911, and published by Cesare Fabris as Memoir 8, of *R. Comitato Talassografico Italiano.*

Here are a lot of hints to the aviator that should be helpful whenever he is unable to obtain current information about the wind aloft. If the wind is with you then, in the *forenoon,* take the 1500 foot level for speed, or the 3000 foot level if it is against you. In the afternoon no advantage of this sort is likely to be available short of at least 5000 feet.

COBBLE-LAYER

Anyone who has ridden in a hurry over a cobblestone road, and also flown close to the surface on a windy day, will admit the appropriateness of this name for that turbulent bumpy layer of rolling and tumbling air-boulders with which every considerable wind thickly strews the surface. Here the velocity frequently and abuptly changes by 100 per cent or more of its average value, as indicated by figure 3, and the direction is nearly as irregular. Here a banking plane may be tipped into a dangerous side slip by a sudden gust against the up-turned wing. Here, too, on turning with the wind one may get into a place where the relative velocity of plane and air is not sufficient to give adequate support; and as there are innumerable up drafts, so too there are as many compensating down currents. The going is unavoidably rough, but the rule for maximum safety, though often ignored, is obvious and simple—*face the wind.* This rule indeed is always followed both in the landing and in the take-off, but in the latter case unfortunately not always obeyed long enough. Turning from against the wind to with it should, for maximum safety, be made only at a good height, above the worst of the surface turbulence, and then on a curve of large radius.

INVERSIONS

Normally the temperature of the lower atmosphere, or troposphere, decreases at every level with increase of height, but there are exceptions to this rule, and besides the rate of increase always is more or less irregular. A very common exception occurs next to the surface. Indeed, during still clear nights this exception is itself the rule, and practically without exception. At such times,

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owing to the rapid net loss of heat by the surface through radiation, the adjacent air, by contact with the cold surface, becomes cooled to a distinctly lower temperature than the air at a slightly higher level. The height to which this cooling extends depends upon the amount of air movement and consequent turbulence or mixing. If this is slight the cooling is restricted to near the surface, but is all the more pronounced. If the movement of the air is appreciable the cooling is less pronounced but extends higher. Finally, if there is considerable wind the mixing so distributes the loss of heat as to be small at any level,e ven at the surface. When, however, the cooling is marked and restricted to a shallow layer the temperature increases through this layer with increase of

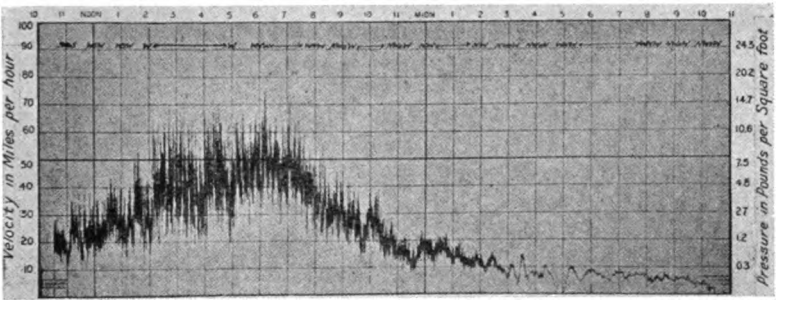

FIG. 3. IRREGULARITIES IN THE SURFACE WIND VELOCITY AS INDICATED BY A PRESSURE-TUBE ANEMOMETER

height instead of decreasing, as is the rule, from the ground up. This is an inversion of the usual temperature gradient, or a temperature inversion, or, for short, just an "inversion."

For a while the air next above a surface inversion layer can slowly blow along over it without rapidly mixing with the colder air or carrying it away, thus providing another case of structure in the troposphere. Appreciable winds, however, do wear away such a layer rather rapidly. They also commonly tend to produce, and frequently do produce, a temperature inversion some distance, perhaps 1000 feet or more, above the surface. The surface inversion, discussed above, occurs, as explained, on still clear nights and is due to loss of heat by radiation, and therefore might be called a radiation inversion. The inversion now

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under consideration may occur any time the wind blows, because it is due to the turbulence or vigorous mixing of the lower air incident to surface friction and the interference to free flow by trees, houses and other irregularities. Turbulence produces a temperature inversion—the turbulence inversion—in this way: Before the wind sets in the temperature of the lower 1000 feet or more of the air may, and often does decrease slowly with increase of height, perhaps only 1°F. in 400 to 500 feet. It even

FIG. 4. BILLOW CLOUD (FORM OF ALTO-CUMULUS); A. J. HENRY, PHOTO.

may increase with height, especially of early mornings, through the lowest levels, as just explained. In either case a complete mixing of the air from the surface up to the level of 1000 feet, say, brings all that air, not to a common temperature, as the stirring of water smoothes out any thermal inequalities it may have had, but to such temperature that wherever, within that layer, a portion of its air may be taken, up, down or sidewise, it will, on arrival, have precisely the same temperature as the then surrounding air at the same level. That is, it will come to such

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temperature that nowhere will a moving portion of it either give heat to, or take heat from, the air with which it at any time is in contact. Obviously, because if the agitated air is not yet in a state of temperature equilibrium with a moving portion of itself, all that need be done to make it so is to stir it up further and mix it more thoroughly.

Now an isolated mass of air that neither gains heat from nor loses heat to the atmosphere through which it passes, obviously must cool with ascent, owing to its loss of heat incident to its expansion against the decreasing pressure. Where the air is unsaturated, so that no fog or cloud is formed, and thoroughly stirred up, as above explained, the rate of this decrease, and therefore the rate of temperature decrease in and of the layer itself is, approximately, 1°F. per 190 feet, allowing for the average amount of humidity. This, as explained, is a much faster rate of decrease of temperature than usually exists in the lower air. Hence the mixing of the lower air by turbulence so redistributes its heat as to make the lower portion warmer than it was, or otherwise would be, and the upper portion colder. Immediately above the top most portion of the turbulent layer the air is undisturbed by vertical convection and therefore distinctly warmer than the upper portion of the agitated stratum. The turbulence inversion (inversion caused by turbulence) is a sharp partition between two portions of the troposphere, one full of irregularities and bumpy, the other smooth-flowing and a joy to the aviator.

Owing to its comparatively low temperature the top of the turbulence layer often is covered with a broad but shallow cloud of the stratus type which, because located at an inversion level, is warmest over its upper surface. But whether clouded or clear this inversion level is difficult of passage by air from either side. If air should pass this level going up it would at once be surrounded by other air lighter, because warmer, than itself and therefore it would drop back. Similarly, air passing it from above would be promptly pushed up again by the denser, because colder, atmosphere it was replacing. In short, this inversion stratum, though very thin and commonly invisible, is an impassable ceiling to rising air from below and an impenetrable floor to falling air

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from above. Gradually, however, through heat conduction, thermal convection, and in other ways, the inversion is smoothed away, and interchange across this level thus made possible wherever the air has within and of itself an adequate supply of water or, really, steam power—whenever its water vapor is sufficient to give abundant condensation, as in a cumulus cloud, and thereby a quantity of heat sufficient to keep it all the way to great altitudes continuously warmer and lighter than the surrounding medium.

It is interesting to note that as the temperature changes almost abruptly, perhaps several degrees, with change of height at the level of this turbulence inversion, so also must the density of the air. And, furthermore, if the pressure gradient, or push that causes the winds, is practically the same, as it seems to be, on either side of, and close to, this level then there also must be here a nearly sudden jump in the wind velocity, from slower in the under, denser air to faster in the lighter air immediately above. However, this change of velocity, seldom more than 1 per cent of the whole, always is too small to be of any practical importance in aviation.

OVERFLOW STRATA

As explained above, any layer of air that is thoroughly mixed up has a certain rate of decrease of temperature with increase of height, and such that the temperature of an isolated mass of like air rising or falling through it will change at the same rate. In such a layer vertical convection is as easy as horizontal gliding over a smooth surface. Left to itself, though, and if unclouded, its vertical temperature gradient or lapse rate (lapse, for short) gradually changes, owing largely to gain and loss of heat by radiation, until it becomes decidedly less, and the layer thereby impenetrable to dry or unsaturated air. Saturated air, however, may be buoyed up to considerable heights, as already explained, because the heat of condensation, or heat rendered sensible as a result of condensation, so reduces the lapse rate that the ascending air is warmer and therefore lighter than the air surrounding it. The extent to which this rising air is warmer and lighter than

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the air through which it is passing depends, of course, on the amount of condensation. This in turn depends on the amount of water vapor present, and that depends on the temperature. Hence, in general, and starting from the same level, saturated warm air is pushed up to greater heights in the process of convection than is saturated cold air. In any case, though, the amount of condensation per given increase of height, and therefore the quantity of heat available for further convection, becomes less and less with gain of altitude, and finally, at one level or another, insufficient to induce further ascent. At this level then, whatever it is, the rising air spreads out in a sheet or stratum that differs in humidity, temperature and lapse rate from the atmosphere of every other level, both higher and lower. In this way, that is, from convections, great and small, including the over and underrunnings associated with general or cyclonic storms, the troposphere is largely built up of overflow strata. They are not, of course, the same from day to day nor from place to place, but everywhere they are always more or less distinct and numerous. They often mark the levels of cloud layers of the sheet or stratus forms, or alto-cumuli of the windrow or billow clouds, figure 4, due to the waves caused by the flow of one stratum over another, much as water waves are induced by wind. Occasionally, two adjacent strata differ from each other so radically that a balloon can float a long distance with the bag in the one and the basket in the other. Of course the identity of each particular stratum ultimately is lost through mixing with others above and below it, whether caused by the vigorous stirring incident to a general storm, or by virtue of the perpetual diffusion and prevalent turbulence over every interface. But so long as it does exist it may be pushed up bodily to greater heights by underrunning air, or depressed to lower levels by an overflow current, with, in either case, a change in its temperature gradient or lapse rate, except in the very unusual case when it initially is that of completely stirred-up air, and a corresponding change in its stability and resistance to penetration by convection in either direction, upward or downward. If the layer is pushed down, without lateral contraction or expansion, by an overflow of air above it

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the pressure on it will be increased by the same amount throughout, but it will be compressed most, and thereby heated most, on the upper side where the initial pressure is least, and compressed and heated least on the under side where the initial pressure is greatest. This changes the temperature gradient in the stratum so depressed, except rarely, as above explained, and in such manner as to render the layer increasingly difficult of penetration—a firmer floor and a more rigid ceiling. On the other hand, if the stratum is lifted to a higher level it is cooled most on top and least at the bottom and its effectiveness as a barrier to convection correspondingly decreased.

It should be noted that in atmospheric convection, and the consequent production of air strata, water vapor plays a most important rôle. With increase of humidity, under constant temperature and pressure, the density of the air steadily decreases, just as it would with increase of temperature at constant pressure. This fact probably accounts for many small waterspouts starting at the surface—starting there because the lower air becomes relatively light through high humidity, analogous to the starting of dust whirls over a dry region due to decrease of density incident to increase of temperature. There is, however, a fundamental difference between the surface waterspout and the dust whirl. The latter consists of dry air made light by increase of temperature, and can ascend (be pushed up) until it has lost a certain amount of its original heat and no further. Not so with saturated or highly humid air. It too, like the dry air, ascends because it is lighter than the adjacent air round about, but it maintains this relative lightness a much longer time through the latent heat rendered sensible by progressive condensation, and thereby reaches far higher levels. In respect to convection dry air and humid air are like unto two men in business, one with a working capital but no reserve assets; the other having, in addition to his ordinary current needs a much greater fund that may be drawn upon whenever required. The one, like dry air, may start well, but his power to expand soon is exhausted. The other, by drawing on his reserve, can take advantage of every opportunity and thus rise to a far higher level of success. Just as it

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takes money to rise high in the business world, so too it requires water vapor to make any considerable ascent in the atmosphere.

"Money makes the mare to go;"
Vapor makes the air to go.

DUST LAYERS

The atmosphere is amazingly full of dust of endless varieties—smoke from kitchen and factory; vegetable fibers from forest and field; pollen from every tree and plant that blooms; salt from the evaporated spray of the seven seas; vast clouds of the desert's finest sand; exploded rock coughed from the volcano's burning throat; and, as if all this were not enough even the ashes, so to speak, of the myriads of meteors that daily flash their way into the outer atmosphere. Dust, dust everywhere throughout the atmosphere from off the earth, from within the earth and from beyond the earth; but though everywhere it is far from being evenly distributed. Here again is structure. Often the lower air, up to the limit of surface turbulence, is so filled with freshly blown-up dust as seriously to restrict the range of visibility. This restriction is most pronounced, owing to the blinding glare, in the presence of bright sunshine, but can be cut then (seen through better) to some extent by the use of amber or red glasses, or even dark glasses. Such a layer has a fairly definite upper surface and produces a distinct horizon. The next densest, but generally much less dense, dust layer extends up to the limit of diurnal convection. It seldom reduces visibility enough to interfere with aviation. The next layer, in the order of decreasing density, is coincident with the troposphere, for it includes all that portion of the atmosphere, and only that portion, to which dust is carried from the surface beneath.

The troposphere has structure—portions or layers—in respect also to its electrification, humidity, and other states, but these are not very sharply defined. We therefore shall pass on to a brief consideration of the little that is known about the structure of the stratosphere.

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UPPER TRADES

Since the stratosphere is much warmer, 30°F. to 40°F., in the polar regions, than the equatorial it would seem that there must be an upper interzonal circulation of the atmosphere somewhat like a mirrored image of the lower—towards the poles in its under portion and from them in its upper levels. The rotation of the earth obviously would affect this upper interzonal circulation in the same manner that it does that of the troposphere, and therefore lead to east winds over the tropical and adjacent regions, and west winds over the higher latitudes. Furthermore, a little calculation based on the temperature of the atmosphere at various levels in high and low latitudes shows that this upper circulation must begin at the height of 10 to 12 miles. This calculation further shows that at that level the average pressure must be nearly the same everywhere, and therefore the average wind at this level very light. Both these conclusions, namely, that the winds 10 to 12 miles above the surface of the earth must be light, and above that level from the east in tropical and adjacent regions, are supported by all the observational data (a fair amount) we have on the subject. They also are supported by figure 1, which shows light winds, becoming easterly, at these considerable heights.

These upper trades are very interesting in connection with the theory of the structure of the atmosphere and its general circulation, but they do not promise to be of much practical importance to the aviator.

TWILIGHT TOP

Another evidence of structure in the stratosphere, but one of no importance to aviation, is the fairly definite level, around 40 miles above the surface, at which the atmosphere is just dense enough to scatter a perceptible amount of sunshine.

AURORAL BASE

The auroras also show structure in the stratosphere, a region in which they occur—60 miles up and beyond—and the region below this level in which they do not occur, or but rarely.

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HEAVISIDE LAYER

The stratosphere furthermore shows remarkable structure, and change of structure, in respect to its electrical state. But always it is so strongly ionized at great heights, or within the so-called Heaviside layer, as to reflect electrical waves and thereby to transmit "wireless" to the ends of the earth.

OZONE LAYER

From the fact that the solar radiation that reaches the surface of the earth does not extend beyond a certain place, or wavelength, in the ultra-violet, and for other good reasons of like nature, we are certain that there is ozone (a particularly active form of oxygen) somewhere between us and the sun. By crucial tests we know, too, that it is not in the lower atmosphere; and by other measurements we know that there is very little of it, only enough to make a layer of gas about one-tenth of an inch thick at the average surface temperature and pressure, and, finally, that this little is most concentrated at about 25 to 30 miles above the surface. It is only a trace in comparison to the atmosphere as a whole, and yet its relation to life is of paramount importance.

SUMMARY

However devoid of structure, therefore, and strictly homogeneous the atmosphere may seem to be, examination shows it to consist of many parts. In respect to vertical convection, temperature, lapse rate (rate of decrease of temperature with increase of height), wind direction, humidity, dust content, light scattering power, auroral occurrence, ionization, ozone density, and doubtless many other things, the atmosphere has structure; in some cases very simple—if we do not inquire too closely—in others complex, but simple or complex always there is structure. And some of these parts are of great importance to the aviator—dangerous to those who know nothing and care nothing about them, but immensely helpful to those who know what they are, where they are and how to profit by them.

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MAN AND INSECTS*

L. O. HOWARD

An article for the JOURNAL OF THE MARYLAND ACADEMY OF SCIENCES should necessarily be thoroughly sound scientifically. It should not be written in a sensational way. It should deal with facts and should reason logically from these facts.

I am inclined to think that the best way of stating the case I wish to present will be in a series of limited and definitely stated paragraphs.

1. The insect type is very many millions of years older than the vertebrate type of which the human species is the latest development.

2. The insect type has, therefore, been tried out very thoroughly under world conditions, while the human species is comparatively in its merest infancy.

3. Many forms of life have been tried, have been found wanting, and have disappeared in the course of the ages; but the insect type has persisted in spite of all cataclysms.

4. The human type may be one of nature's experiments that will fail. It has not been in existence long enough to have been thoroughly tried out.

5. The human species, in spite of its physical disadvantages, has jumped to the fore with unexampled speed owing principally to the evolution of the quality known as intelligence. Through this intelligence, it has either destroyed or controlled or converted to its own use nearly all other forms of life.

6. In its very rapid increase and spread, however, the human species has so disturbed the balance of nature as to favor the increase and spread of disease-bearing microörganisms and as to encourage enormously the multiplication and spread of injurious insects. In its efforts to feed its increasing millions, it has fed increasing billions of insects.

* Received for publication March 25, 1930.

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7. Prophets of evil tell us that human over-population of the world is approaching, and approaching rapidly; that mass starvation is sure to come; that birth control is necessary if greater production of plant food cannot be stimulated or if new foods cannot be invented.

8. There is a third way of postponing the coming of the starvation era, and that is by the stopping of all waste.

9. Probably the greatest of these wastes is the tremendous but unnecessary tribute that we pay to insects. In the United States alone, the labor of one million men each year is lost through their damage to crops and to our other vital interests. And this damage is increasing. The problem is very much greater than it was even twenty years ago. In order to get the quickest and most abundant food supplies, we are growing our crops in many instances in exactly the way to favor best the increase of crop pests. The cotton boll weevil, for example, might never have been heard of as a serious crop pest if it had not been brought by accident across the Rio Grande and found itself in a whole great State largely devoted to the growing of its favorite food and growing it in just the way to favor the beetle's multiplication to the extreme. The European corn borer, to take another example, would do little harm if we did not farm our corn lands just as we do.

10. It is necessary that we should understand present conditions—that we should understand that insects are our dangerous rivals for the food supplies of the world, and that they are our important rivals and enemies in many other ways. Then it will come about that many men will turn their attention to insect problems. Many men of sound training will study every aspect of insect life. Competent chemists, physicists, botanists, agricultural engineers and agronomists will take the findings of the increasing number of entomologists, and upon them will base measures for the relief of humanity. The time cannot come too soon. Teachers of biology should at once begin to learn and to teach entomology.

Having thus stated briefly and rather definitely what appears to me to be the situation and the general course that should be

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pursued, I think that it may be of interest to elaborate some of the points.

In the paragraph numbered five, we have referred to the physical disadvantages of the human species as compared with insects. From the engineering point of view, the limb of a vertebrate, with the skeleton inside, other things being equal, is three times weaker than the insect limb having its skeleton on the outside. This outer skeleton of the insect is composed of chitin, an albuminoid that is attacked neither by alkaline solutions nor by dilute acid. It does not grow brittle with age like the bones of vertebrates. The muscles that are exposed in human beings to the slightest injury and are attached to the inner bones, are, in insects, covered and protected by the chitin, and they function better from their numerous attachments to ridges on the inner side of the covering. The insect skeleton is composed of waste material, while the bony skeleton of man is composed largely of proteins and inorganic materials, chiefly lime and phosphorus. The starches and other substances that make the skeleton of insects, abound in nature; while the diet of man must be selected carefully to include the substances needed for the growth of bone. The blood of insects penetrates to every part of the body, just as it does with us, but the air that purifies the blood also penetrates to every part of the body instead of being confined to the lungs. When insects are born, there is no long period of helpless infancy; they take care of themselves from the start. There is no feeble old age with insects; when their work is done they die before their faculties or their structure have begun to degenerate. There are no bones to grow brittle with age; chitin seems to grow stronger with age.

Together with the advantages already pointed out comes the tremendous advantage of rapidity of multiplication and rapidity of growth and the consequent rapidity of the accommodation of a species to a changed environment. Insects, for example, have all the way from one to twenty generations a year, nature trying slowly to make each generation more fit than its predecessor. Place the number at five per annum, as is the case with the cotton boll weevil. Then, in the thirty-five years this insect has lived

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in the territory of the United States, it has had one hundred and seventy-five generations. An equal number of generations for the human species would fill more than three thousand years. The advantage in the slow process of evolution and accommodation to changed conditions is evidently enormous.

As to rapidity of multiplication (which differs very greatly with the different forms of insect life) two rather striking examples may be cited. I have shown that, with the common house fly, a single over-wintering female may have, between April 15 and September 10, 5,598,720,000,000 descendants. This seems almost incredible, but, given larval food, it is possible. It is not, however, great as are the figures, as startling as the estimate made by Prof. G. W. Herrick of Cornell, of the ponderable mass of the descendants of a single cabbage aphis in Central New York in less than a year. Although a single aphis weighs little more than a milligram, the ponderable mass of its descendents in less than a year would be more than 822,000,000 tons! In pounds, this would be 1,644,000,000,000. Estimating the human population of the world at two billion and the average weight at the exaggerated figure of 150 pounds, the total human weight would be 300,000,000,000 pounds. In other words, the plant-lice descended from one individual of one species in a single season would weigh more than five times as much as all the people of the world. Of course, in this estimate we must grant the existence of food enough for this mass, which of course is impossible.

I have spent the larger part of my time during the past two years in writing a history of applied entomology, and it is interesting to note how little attention has been paid in the past to the insect problem, except for occasional great emergencies like swarms of migratory grass-hoppers, and at the same time how the problem has been growing. Undoubtedly, wherever a center of human civilization had its beginnings, just as soon as food began to be grown on a sufficient scale to feed many people, certain injurious insects began to increase in number. New opportunities for their increase were being offered to them—their increase was really being encouraged. If we had the records of

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lost civilizations, no doubt these losses by insects would appear; and it is quite within the bounds of possibility that insects have aided in the destruction of past civilizations—such, for example, as those that existed in Central America. Little attention was paid to insects, however, except when great outbreaks occurred, until within the last one hundred and seventy years; and then for more than a hundred years insects were studied by a few men here and there simply as a part of the animal kingdom. They were brought into collections, and classified and named. Their study, however, was considered a trivial pursuit. Within the past seventy years, however, a new type of entomologist has appeared—the economic entomologist, and there has grown up rapidly an increased appreciation of the importance of the study of insects; and the economic entomologists have been increasing rapidly in number, particularly during the present century. The United States has led in this work, and perhaps still leads in the number of persons engaged in entomological research with its economic applications distinctly in view. But other countries are rapidly coming to the front. Entomological problems have seemed more important in the newer countries. The dominions and colonies of the great British Empire have, therefore, felt a greater need for entomological research than most other parts of the globe, with the exception of the United States, and there has been built up in the British Empire many strong research bodies centered in an Imperial Bureau in London.

But possibly it is not the dramatic outbreaks of a comparatively few spectacularly injurious species that bring about the greatest loss. Take agriculture in Europe, for example, where, on account of the small holdings and close methods of cultivation, these great outbreaks rarely get a start. It has become the custom to estimate a normal crop for a certain piece of land. But it seems to the writer that the so-called normal crop would be greatly enhanced if all unnoticed insect damage were eliminated. There are undoubtedly minute unnoticed insects that are constantly lowering productiveness; there are millions of tiny jaws and beaks gaining nourishment from cultivated plants. There

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must be some way of destroying these creatures and of thus minimizing this damage.

Moreover, there are bacterial diseases of plants and diseases caused by other microörganisms. Upon such diseases there has been built up a great branch of applied science known in this country as phytopathology.[1] But it is beginning to be realized that possibly the majority of these plant diseases are carried and spread by insects, and therefore the control of insects becomes doubly important.

We have not attempted so far to particularize the broad nature of the harm done by insects to the human species. Not only do they consume from 10 to 20 per cent of everything that we try to grow, but they feed upon practically all the stored foods and upon an infinite number of materials that are of use to us. They also affect seriously the health of man and of all domestic animals; and by the carriage of disease, not only to man but to plants, they intensify greatly the problem as it appeared to us only a few years ago.

There is no doubt in my mind that the human species, with its intelligence, will eventually meet this great problem, and that it will bring insect life under control, but down to the present time the problem has comparatively been ignored. In future, not only must the minds of scientific men turn in this direction, but many more men must be educated in such a way as to enable them to conduct profitable research; and, what is more, we must face the fact that we must study our present ways of doing things and particularly our present ways of growing food, and that we must make radical changes in order to bring about the best results.

Intelligence will win out in the long run; but the human species must turn aside in its race and concentrate a great deal of its "God-given" intelligence on its strongest rival, the insects.

[1] In Europe, the term *phytopathology* is applied to damage done by insects as well as by parasitic microörganisms and viruses.

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THE EQUIPMENT AND PERFORMANCE OF THE PRESENT DAY MILITARY AIRPLANE*

JAMES E. FECHET, D.A.S.

Major General, Chief of Air Corps, United States Army

While in outstanding flight achievements the accomplishments of the Army Air Corps in 1929 were of a gratifying nature, more tangible results were obtained along the line of the development of aeronautical equipment and in the endeavor to make flying safer.

The spectacular flying achievement of the year, if such it may be called, was the refueling duration flight of the Army plane "Question Mark," which later paved the way for flights of this character by a number of civilian aviators and which finally culminated in the astounding duration record of 420 hours and 21 minutes, or 17½ days, by Dale Jackson and Forest O'Brine. No further proof is required to convince one of the wonderful strides which have been made in the development of reliable airplanes and engines.

The 6½ days' duration flight of the "Question Mark" not only tended to demonstrate the high standard which has been reached in the development of military airplanes of the cargo type, but the distinct advantage of refueling planes in flight during military operations.

Quite a number of notable long-distance flights have been made during the year in various types of service planes, thus affording conclusive evidence that the Air Corps is now being supplied with flying equipment of the most modern character. Utilizing a transport plane, a flight was made from Dayton, Ohio, to France Field, Panama Canal Zone, a distance of 3130 miles, in 38 hours and 40 minutes.

A transport plane was the medium of transportation of the Hon.

* Received for publication January 15, 1930.

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F. Trubee Davison, when he was piloted on a 7000-mile tour of inspection of Air Corps fields and stations in the United States.

The efficiency of the attack type of airplane, the A-3, was demonstrated during a flight of nine of these planes, assigned to the 3rd Attack Group, from Galveston, Texas, to Miami, Florida, and return. A most notable flight, also made in an A-3 plane, was the one made by two Air Corps officers, Lieutenants Larson and Carr, from France Field, Panama Canal Zone, to Kelly

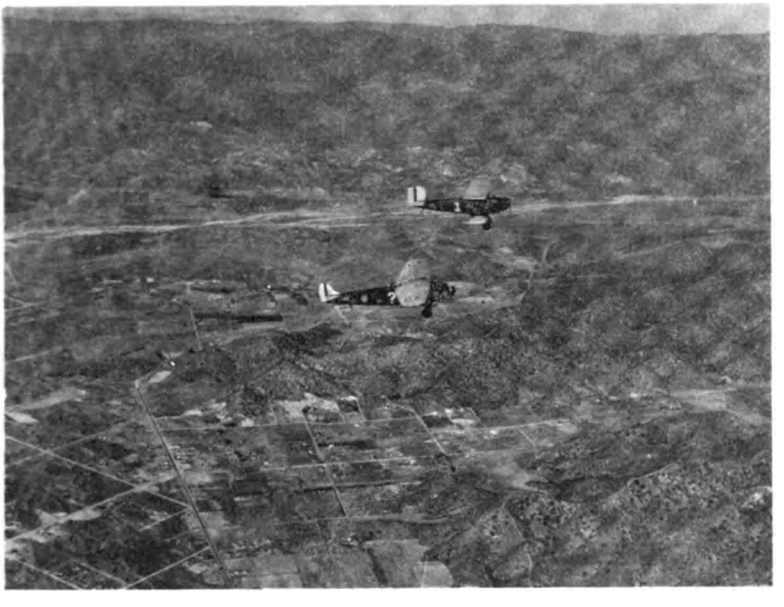

FIG. 1

Field, San Antonio, Texas, a distance of 2030 miles, which they accomplished in one day. The southbound trip from their home station to Panama had been made in easy stops. The return trip of 2030 miles, which was made in one day, constituted a notable record.

Observation type planes were also not to be denied in the matter of long-distance records. A daylight flight from Washington to Havana, Cuba, followed by another one on the return journey constituted one notable example. Another was the dawn-to-

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dusk flight of Captain Ross G. Hoyt from Washington to San Antonio, Texas, which he followed up the next day with a similar flight on the return trip.

Although the fastest plane of them all, the Pursuit type, is not utilized expressly for long-distance flying, several have been made so through the addition of extra fuel tanks. In a Pursuit ship so equipped, Captain Hoyt started from New York with the

FIG. 2. LEFT—CAPT. A. W. STEVENS AND CAPT. ST. CLAIR STREET DRESSED FOR HIGH ALTITUDE FLIGHT

intention of flying to Nome, Alaska, and return. He reached Nome, but on his return trip experienced motor trouble and a forced landing necessitated the abandonment of the flight.

Two Observation type planes and one Pursuit type, with five pilots, were flown from France Field, Panama Canal Zone, to Langley Field, Virginia, and return, one of the objects of this long journey being to enable the airmen to participate in the annual aerial gunnery and bombing matches at Langley Field, Virginia

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The latest type of Bombardment plane, now in use by the Air Corps, also has a rightful claim to long-distance flight records, for nine of them, belonging to the 2nd Bombardment Group at Langley Field, Virginia, were flown to Rockwell Field, Coronado, California, in exceptionally fast time. The return flight to Langley Field was made in easy stages.

And last, but not least, a Training plane also claimed the spotlight by virtue of a round-trip flight between March Field, River-

FIG. 3

side, California, and Washington, D. C. Captain Harper, the pilot, flew a PT-3A advanced training type plane, and negotiated this flight across the American continent and return in a total flying time of 85 hours and 35 minutes.

High altitude flying was not neglected, for quite a number of such flights were made, chief among which being the one by Lieutenant Harry A. Johnson, pilot, and Captain Albert W. Stevens, photographer, when a record of 35,611 feet was attained. Two Army flyers, assigned to the 25th Pursuit Squadron, executed

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combat maneuvers in Pursuit planes at an altitude of 25,000 feet.

A most noteworthy flight, even though it was of short duration, was the one made on September 24 last by Lieutenant James H. Doolittle, of the Air Corps. This skillful Army flyer, sitting in a covered cockpit, with his vision entirely cut off, and relying solely on his instruments, was able to take off from the airport, fly from it, return to a given spot and make a landing. Lieutenant Doo-

FIG. 4

little's achievement, which created a tremendous amount of interest, brought to the attention of the world at large the gratifying progress which has been made to promote greater safety in flying, and has served to engender hope in the hearts of airmen that fog, their deadly enemy, is in a fair way of being conquered in the not distant future.

A striking demonstration of the great advances made in the science of aerial photography was recently given by Captain Albert W. Stevens, one of the foremost photographers in the

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Army Air Corps. This officer, piloted by Lieutenant John D. Corkille, proceeded on a photographic expedition from Dayton to the Scenic Northwest, and during the course of his work made an aerial photograph of Mount Rainier from a distance of 227 miles.

As may be gathered from the foregoing, the Army Air Corps has six distinct types of planes, viz: Pursuit, Attack, Bombard-

FIG. 5. FORMATION OF BOMBARDMENT PLANES

ment, Observation, Cargo and Training. Two types of Pursuit planes now in use by the Air Corps are the Curtiss P-1-C and the Boeing P-12, the former powered with Curtiss D-12-E (water cooled) engine, the latter with a Pratt-Whitney radial air-cooled engine. Several new types of Pursuit planes are now being experimented with to ascertain whether they possess a marked superiority over those now in use.

The present Attack airplane, with which the 3d Attack Group of the Air Corps is equipped, is a modification of the Standard

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0-1 (Curtiss) Observation type, and is known as the A-3. This plane meets Air Corps requirements better than any type previously used.

The standard Bombardment planes now in the service are the Keystone LB-6 and LB-7 types, both equipped with air-cooled engines, the former with two Wright "Cyclone" B-1750 engines and the latter with two Pratt-Whitney "Hornet" R-1690 engines, both types developing 525 horsepower each. The performance

FIG. 6. TRANSPORT OR CARGO AIRPLANE

and flying qualities of these bombing planes greatly exceed those heretofore in use by the Army Air Corps.

Four different types of Observation planes are now in use, the Curtiss 0-1E, the Loening Amphibian 02-A, the Douglas 02-H and 02-K. The 0-1E is equipped with the Curtiss D-12-E engine, the Amphibian with an inverted Liberty engine and the two last-named types with Liberty engines.

There are no less than seven different types of Cargo planes in use by the Air Corps today, all but one of which are tri-motored types. The exception is a Douglas C-2, which is powered with a

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single Liberty engine. All of these Cargo types have been used to good advantage in the flying operations of the Air Corps.

The Training type of plane used at the two Primary Flying Schools of the Air Corps and known as the P-T-3 (Primary Training) is powered with a J-5 (Wright Whirlwind) air-cooled engine. This plane is a decided improvement in all respects over the old JN-4 Training plane. Its use has aided greatly in

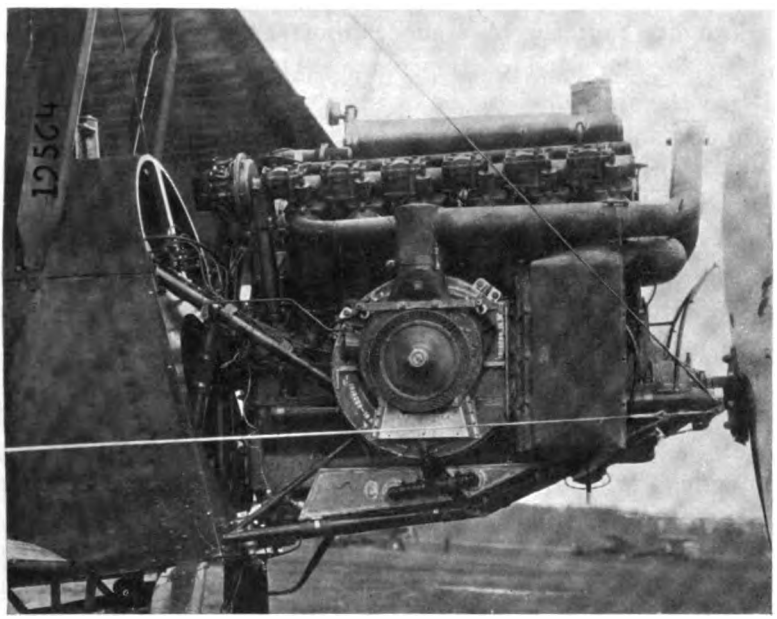

FIG. 7. SIDE TYPE SUPERCHARGER ON LIBERTY ENGINE

facilitating the flying instruction to students and in reducing accidents to a considerable extent.

With respect to power plant development, considerable headway has been made in the use of air-cooled engines, for Bombardment, Cargo and Training types. Whether such engines can be used to better advantage in Pursuit, Attack, and Observation planes is a question for the future to decide. Far from abandoning the water-cooled types, it now appears that their use may be prolonged for an indefinite time, particularly in view of recent

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developments in cooling processes. The successful application of high temperature liquid cooling to water-cooled engines Prestone cooling as it is popularly known, making possible the reduction of the size of the radiator required about 70 per cent, has resulted in greatly improved engine operating efficiency, since the reduction effected in the weight, and resistance of these engines will enable airplanes to carry greater loads at greater speeds and with more economy of fuel. It may even be possible to eliminate radiator resistance almost entirely by placing the radiator in the wing of the plane. Only time alone can tell whether the air-cooled engine or the Prestone water-cooled engine will prove superior in general all-around use.

Those interested in aeronautics are no doubt familiar with the strides which have been made in high altitude flying through the development of the supercharger, a device which, connected to an airplane engine, overcomes the handicaps incident to flying in rarefied atmosphere by enabling the engine to function under sea level conditions up to a certain altitude. Equipping a photographic airplane with a supercharger made it possible for two Air Corps officers to reach an altitude of 37,854 feet, from which height the photographer made a good photograph with a single lens camera which covered an area of approximately 30 square miles.

Aircraft development in the Army work has been chiefly devoted to the improvement of the aerodynamical, flying and structural characteristics of service types and the adaptation thereto of the new types of air-cooled engines recently brought out.

Development work in radio has been constantly going on. Radio receivers of greater sensitivity are now being used, and only recently, at Chanute Field, Illinois, radio communication between the plane and ground station was carried on uninterruptedly over a distance of 275 miles for nearly three hours.

As mentioned previously in connection with Lieutenant Doolittle's blind flying experiment, gratifying progress has been made with respect to various aids to flying. The part the earth inductor compass has played in long-distance over-water flights is too well known to bear repetition. The radio beacon is another

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device, the value of which in flights under unfavorable weather conditions or over country devoid of landmarks is well known. Experiments are now being conducted with a new type of altimeter calculated to give a pilot flying in fog at night an accurate estimate of his distance above the ground.

It is difficult to make any comparison between planes made for commercial purposes and those for military use. It is logical to expect that the commercial type plane should be surrounded with more devices or built in such a manner as to make it a safer vehicle of transportation than a military plane. Safety is the paramount factor in commercial planes, for too much stress cannot be placed on the importance of transporting passengers with a minimum of risk. But in designing commercial planes with the safety as the essential quality, certain elements are necessarily sacrificed, such as speed, and maneuverability. Military airplanes, on the other hand, are designed primarily for speed and maneuverability, although the safety factor is not neglected. The idea must not be lost sight of that in time of peace military flyers are trained for duties which would devolve upon them in time of war. They must, therefore, be trained in types of airplanes which would be used in military operations. And in military aerial operations, the pilot with the speedier and more maneuverable plane has the greater chance of staying in the air the longest and emerging victorious from the fray. In order to obtain such factors as speed, maneuverability and other characteristics essential to aerial combat, certain safety factors in airplane design must be reduced to minimum for the genius has not yet come to the front who can combine both in an airplane and maintain in supremacy for it.

I always feel sure that the most interesting division of aviation is the Operations; that is, that part of aviation concerned with the actual flying and handling of the planes themselves. It might be well at this time to relate the procedure of flying from Bolling Field, Washington to Wright Field, Ohio. Instead of procedure one might better say "routine," for such a flight is merely one of the routine tasks of our Air Corps personnel.

Let us assume that one of the officers at Bolling Field is ordered

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to Wright Field to attend a conference there, and that he has been ordered to travel by air. The Operations Officer at the field being apprised of this flight chooses an observation plane, a two-seater plane with a motor of about 400 or more horsepower. He calls up the hangar where this plane is housed and informs the crew chief of this particular plane that early next morning the plane will be held available to fly to Wright Field, that no passenger has been chosen and that the crew chief may go as passenger if not already posted for guard duty within the next day or so.

Assuming that the plane in question has just returned from another flight the crew chief makes the routine inspection of the plane required by our Visual Inspection system. The plane is gone over in a very thorough manner, the crew chief in a systematic way inspecting every important part of the plane and motor. This is the daily inspection, and must be gone through every day the plane has been flown before it is allowed to be marked "In Commission." As the mechanics, and this includes the crew chief of that plane and his regularly detailed assistant, complete the inspection and adjustment of each section of the plane the crew chief himself marks his initials in the proper space on a chart on the wall, of the hangar. There is a separate chart for each plane. The mechanic's initials show that the condition of the part he has inspected is satisfactory. The airplane itself is finally inspected and cleaned, the necessary adjustments made and everything pronounced satisfactory. The motor is then also inspected and adjusted and the plane then "serviced," that is, the oil and gas tanks and the radiator are filled. As the capacity of the main gas tank is only 110 gallons and the proposed flight is to be beyond this capacity the crew chief puts on an auxiliary tank which is slung below the belly of the fuselage. This tank holds an extra 60 gallons of gas. Everything being satisfactory, the crew chief reports the plane as being in commission and waits for the following day.

On that day everything at Bolling Field is fine, as regards the weather. Before obtaining a clearance from the Operations Officer for his cross-country flight the pilot consults the "weather

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board." On this board are detailed weather reports from all the Army airdromes in the East and an additional report from Cumberland, Maryland, where we have stationed a meterological detail.

These reports come over the radio early in the morning, immediately after observations have been made by the meterological men at the various stations; and again at noon, after similar observations. Every Air Corps station throughout the country maintains such a weather board, where are tabulated the periodic reports from fields in that part of the country.

Let us say that Wright Field, near Dayton, Ohio, the pilot's destination is also enjoying fine weather. The pilot runs his eye down the chart. He sees that flying conditions are excellent, visibility the same, ceiling unlimited. Gentle surface winds, coming from the West, getting stronger aloft. He notes the temperature on the ground, and the rising barometer.

Let us next assume that flying conditions at Uniontown, Pennsylvania where we have Burgess Field, are, as usual, bad. Flying conditions dangerous, ceiling 1500 feet, and the ominous report—"Clouds on the Mountains." Now, however poetical that sounds, these few words "Clouds on the Mountains" mean a great deal to the flyer who is hoping to get across the Alleghanies. They usually mean that he stays on the ground until a better report comes along, especially if the bad report from Uniontown is supplemented with a similar one, as is often the case, from Cumberland.

But at noon, good weather often breaks the bad, over the Alleghanies. This change would then be radioed out with the noon reports. Bolling Field would get it, and the Operations Officer would then feel safe in giving a clearance slip to the pilot for his flight westward.

From the map that is furnished the pilot, he notes the compass course and flies his plane accordingly. He notes the altitude of the first range of mountains, 1600 feet just east of Charlestown, but he is far higher than this when he passes over Leesburg and sees the Potomac River turn north, away from his line of flight, Leesburg he sees by his map should have its name marked on the roof of some building in town.

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When he crosses the Shenandoah River just east of Charlestown he has gone 50 miles. He notes the elapsed time it has taken him to fly this 50 miles and calculating the theoretical time it would have taken him according to his air speed indicator, he is able to tell whether or not he is bucking a head wind or being helped by a tail wind. If he has held to the compass course of 305 degrees indicated on the map and has found himself four miles south of Charlestown he knows he is on his course and that there is no side wind drifting him one way or the other off this course. If there is any appreciable drift he makes allowance for it and flies his compass course accordingly.

About an hour after he has taken off from Bolling Field he should pick up the Potomac River again, and a few minutes later find himself over Cumberland. Below him is the emergency landing, field, and most pilots take a good look at this field when passing over it, it is a handy place to land when the weather suddenly turns for the worse over the high country between Frostburg and Uniontown. As he leaves Cumberland he changes his course slightly so that his compass reads 294 degrees. This course heads him for Uniontown, Pennsylvania, where there is an Army airdrome just west of the Alleghany range. It also takes him more or less over the National Highway, and while he is flying along at about 100 miles an hour through the air he can watch the cars on the highway below him struggling up-grade or slipping cautiously downhill.

When he gets over Uniontown he has flown 160 miles. On Burgess Field he notes the "control panels," panels that are laid out on the ground in the shape of arrows, one pointing east and the other west. If either arrow is crossed by another strip panel, the pilot knows, without landing to inquire, that there is bad weather reported in the direction that the arrow in question is pointing.

In such a case he must land for more detailed information before taking the chance of continuing his way. If the arrow is uncrossed he knows that all is well between Uniontown and Dayton.

If the pilot has taken off from Bolling Field much after noon

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he will have to speed up his plane in order to reach Wright Field before nightfall. If he has been delayed by head winds it is doubtful whether he will make it before darkness has set in even though he run full speed, and this is something the careful pilot does not care to do. Motors, as well as horses, should be nursed along on long trips and in dangerous places.

After the Monongahela and the Ohio Rivers have been passed the pilot is still over some very bad country until Zanesville has been reached. Broken country, small, but ragged hills, patches of timberland. Hardly a decent pasture in which to make a forced landing until he reaches the prairie country. There is no need for a pilot to worry if nightfall does overtake him in this section of the country. The beacon lights followed by the mail and transport pilots shine up brightly, it is often possible to see several of them in line, one beyond the other.

The lights of Newark, Columbus and Springfield light up the sky. Somewhere between the latter two cities the pilot will turn off and bear south.

Already those on duty at the Operations Office at Wright Field, notified by radio from Bolling Field of the pilot's departure from the latter place, are getting anxious. The beacon light is revolving, so many seconds to each turn. Red lights are on the hangar tops, the border lights are on around the airdrome, and along this border line are green lights at certain spots. These green lights show the place of safest approach that is, where the approach to the field is clearest of obstructions.

As the pilot flies over the field he notes the landing T, a T-shaped indicator that swings into the wind and indicates the direction from which the wind is blowing. He then picks out the best approach along the leeward side of the field and with the landing lights lighting up the field, he makes his landing.

Taxying up to the hangar line, the pilot's work is not yet completed. In each plane there is a blank form which he must accomplish. On this form he must note his time of departure, his time of landing, the elapsed time and the place of take-off and landing.

Of course, he also signs his name and that of his passenger.

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He notes the flying qualities of the plane, the actions of the instruments, the behavior of the motor, in short all those things which the crew chief would be unable to determine himself by running the motor with the plane on the ground.

From these reports the crew chief determines whether or not the plane and the motor are functioning properly. From these he keeps his record of their flying time. He himself records upon this form the amount of gas and oil that go into the tanks of the plane, and this record is transcribed on the plane's individual chart when the plane, the blank form, and the crew chief return to their home station.

Perhaps to most of you the narrative of this flight was interesting. To us in the Air Corps it is just as interesting to see the workings of this Visual Inspection System, for these records of the flight are but part of this system. Sometime previously I mentioned the result obtained by the Air Corps in making flying safer. It might be well, then, to mention here in closing that it has been the operation of this Inspection System, the faithful observance of its regulations, that has reduced forced landings and accidents due to mechanical failures by fifty per cent in our Army Air Corps.

This I believe ranks with any achievement in any aerial organization in the world, for of all things that have been done in this direction it has played a major part in making flying safe, safe for those of us who are now flying, safe for all of us who will soon be flying.

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OLIVER HEAVISIDE*

A Sketch of His Work and Some Reminiscences of His Later Years

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It is strange and almost incredible that although Oliver Heaviside died only five years ago and was a mathematical physicist of worldwide fame during the last fifty years of his life, very little—indeed, exceedingly little—is known about him as a man rather than a scientist. His writings while abstruse to a degree nevertheless do give us some clue to his personality. He began his writings when twenty-one years old and continued well toward the end of his life.

The scientific world, or at least the leading mathematicians and physicists, realized, no doubt, his genius quite early but it was only during the last years of his life that he loomed large in the world of science when his name rightly ranked with Galileo, Newton, Kelvin, Fitzgerald, Faraday and Gibbs. Today every scrap of paper that belonged to him is eagerly sought and many of his manuscripts and books are securely housed in the library of the Institution of Electrical Engineers, London.

Oliver Heaviside was born in London, May 18, 1850 and died in Torquay, February 3, 1925. This much is certain. He no doubt inherited his marked artistic talents from his father who was a prominent engraver and probably inherited his enthusiasm for knowledge from his mother, who, apparently was his first—and only known teacher. The most complete sketch of Heaviside that I have seen appeared some months ago in *Electrical Communications*. In this number are given reproductions of two pen and ink sketches made by him. One of these was made when he was a child of eleven. They are really remarkable and it seems strange how he escaped being an artist rather than a

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scientist. It is unbelievable that in spite of most exhaustive research no one has so far been able to find where and when he attended school nor where he lived and wrote the great mass of manuscripts now in large part published.

His first paper was done as above stated at the age of twenty-one and while of very great interest did not discover a knowledge of the higher mathematics but shortly afterwards he had mastered not only the calculus but the very complex field of infinite series. Fourier's work fascinated him and he often referred to it. Judging from his papers written at about the age of twenty-five years he understood, or at least largely had mastered Maxwell's and Kelvin's works.

I quote from *Electrical Communications:*

"It is certain that from 1876 Oliver subjected himself to strenuous training. His habit was to retire to his room at about ten o'clock at night and to work there until the early hours of the morning. He closed his door and windows, lighted his oil lamp, and allowed the air to become hot and stifling. He worked also during the day, in seclusion. In order that he might not be disturbed, his food was placed outside his door, and there it remained until he was disposed to take it. Thus he transgressed most of the rules that modern conventions prescribe for health. On the other hand, he enjoyed walking, and occasionally he had more vigorous exercise, for he was a good gymnast."

The results of all of this work was apparent. Manuscript after manuscript was presented to scientific and technical papers but generally they were rejected. The Royal Society failed, as other learned societies and as individual men of the first rank in science also did, to appreciate the great value of his work.

I again quote from *Electrical Communications* in reference to one of the papers sent to the Royal Society:

"Both our referees, while reporting favourably upon what they could understand, complain of the exceeding stiffness of your paper. One says it is the most difficult he ever tried to read. Do you think you could do anything: viz., illustrations or further explanations to meet this? As it is, I should fear that no one would take advantage of your work.

Yours truly,
Rayleigh."

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The world will always be indebted to Mr. C. H. W. Biggs, the editor of *The Electrician*. He had the courage and foresight to publish many of his manuscripts and as a result we now have five valued volumes of Heaviside's writings. These volumes cover wide fields of mathematical physics, particularly perhaps the field which pertains to the transmission of speech by electrical means.

Except for Heaviside's work, long distance telephony might have been indefinitely delayed. He first developed the correct theory for distortionless transmisson of speech, discussed the use of loading coils, suggested their design, spacing, etc. Professor Pupin some years later proved by experiment the correctness of Heaviside's theory. Much of his writing deals with the propogation of electric waves and it is of interest to know that he and Hertz were frequent corespondents.

I quote from some of Hertz' letters:

"I more clearly understood your methods from your letter than from your book, where they lie hidden beneath a great number of special cases. I am quite of your opinion, that you have gone further on than Maxwell, and that if he lived he would have acknowledged the superiority of your methods."

"I find it so difficult to follow your symbols and your very original mode of expressing yourself. You know mathematical symbols are like a language and your writing is like a very remote dialect of it."

"The fact is that the more things became clear to me and the more I then returned to your book, the more I saw that essentially you have already made much earlier the progress I thought to make, and the more the respect for your work was growing in me. But I could not take it immediately from your book, and others told me they could hardly understand your writing at all, so I felt obliged to give you warning that you are a little obscure for ordinary men."

Professor John Perry, famous as a telephone engineer and as the author of many works and papers of scientific and technical interest wrote:

"Now I rank Heaviside with those two men (Kelvin and Fitzgerald) but I never pretend to be able to read Heaviside. I wish I could, and so

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do a lot of people like me. . . . . Somebody will have to write down Heaviside to our level."

Heaviside's writings are most certainly difficult to follow but they are fascinating not only because of their mathematical uniqueness but because of the human touch so often contained in them. Interspersed among the most profound mathematical deductions we find opinion after opinion of a "dyed in the wool" mathematician and the "scienticulist," to him were "contemptible men that act or talk as if they were mathematicians and scientists but who do not understand what they are talking about."

While Heaviside's fame rests largely on his contributions to the theory of electric communication, every electrical engineer that has anything to do with alternating current phenomena owes him a great debt of gratitude. It is doubtful, however, if he realized the importance of a statement in a few lines to the effect that Vector representation of alternating current phenomena could directly be obtained from the differential equations if for $\frac{\partial}{\partial t}$ was substituted $j\omega$.

Kennelly and Steinmetz saw the importance of this statement and made full use of it.[1] Steinmetz may indeed be said to have devoted his life to its application in electrical engineering. He wrote volume after volume based upon these few lines of Heaviside.

My interest in Heaviside dates back to 1892 when I first tried to read and understand his articles appearing in the London *Electrician*.

Later, when I came to know him, Heaviside asked me if I remembered a loose insert in one of the numbers of *The Electrician* on which was a statement by the editor that there was a question about continuing his articles, and continued by saying that if a single person could be found who had read them their publication would be proceeded with. But alas! Heaviside told me, not one reply was received. Pity—I know of at least two men who

[1] Kennelly apparently independently introduced $j\omega$ about the same time as Heaviside.

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would have replied favorably had the slips found their way to Lynn, Massachusetts.

Since that time and until 1923 I made a point of asking all English scientists that I met if they knew Heaviside but found none. In the same year at Rochester, while reading a paper on "Operational Calculus," I met Dr. Silberstein who knew Heaviside and kindly wrote me a letter of introduction. Armed with this I arrived at Torquay, June 7, 1924, and mailed him a note with the letter of introduction and asked for permission to see him the next day.

His home address, which was Homefield, Torquay, was obtained in a music store owned by his brother. I was incidentally told that he would not see me, that he saw no one but a police officer who assisted him to get supplies, etc. Later I learned that the policeman's wife cooked at least some of his food. His old housekeeper had gone mad during the war.

Upon arrival at his house which is beautifully located, but quite dilapidated, I saw the door plastered over with old bills marked "Paid" in red pencil and a small envelope on which was written, "To be called for," and which contained the following note:

"Prof. E. J. Berg:

Being deaf and living upstairs I leave this out in case I do not hear you. My full address is Mr. Oliver Heaviside, Homefield, Torquay, and letters always reach me through the letter box. I have been very ill the last winter and am wishing for some fine dry weather to begin summer convalescence. Things are much changed here and I have nothing to offer you. So you must bring your own grub if you are likely to feel hungry.

Yours, etc., O. Heaviside."

The note certainly indicated that he could not and would not see me. Turning homeward I met his "Bobby" Friend. After some coaxing he agreed to return with me to try to let me get a glimpse of Heaviside. The officer told me that Heaviside, while quite hard of hearing, was far from deaf. After blowing his whistle, poking a stick of wood through the letter slot, etc., Heavi-

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side came down and opened the door—a bent, old man of very fine features, snow-white hair and beard, dressed in a rather worn suit, but his linen was immaculately clean. He asked if I had read his note. Yes, but I wanted to see him to tell him how in America at least, most interest was manifested in his writings. I wanted to express my gratitude for what I had learned from them and if possible would like to discuss certain parts of them with him.

He answered as follows:

1st. The fact that I wrote my notes from The Imperial Hotel was sufficient reason for not seeing me—he had no use for millionaires.

2nd. He would have nothing to do with a man who tried to get access to him by flattering.

3rd. He never discussed his writings. He had forgotten all about them.

This seemed rather final. I noticed, however, that he smoked and asked if, since I had forgotten my tobacco, he would give me a pipeful to use on the way back to the Hotel. Yes, he started to go upstairs and left the door open enough so that I could see the hall and in it a long ladder. I asked him not to bother about the tobacco since it would involve his climbing around the ladder in walking upstairs. Nevertheless he asked me to come up to get the tobacco—and I was inside. Thus began a most memorable set of visits which culminated in real friendship.

The halls down stairs and the study upstairs were plastered with diplomas, and clippings, many newspaper pictures or inexpensive prints of famous people. Down stairs I recognized the A. I. E. E. honorary certificate signed by E. W. Rice. When I told him that Mr. Rice was president of the General Electric Company and a friend of mine he showed some interest. Close by was a large diploma—in Latin—signed by the last German Emperor. "That Fool," he exclaimed. He was very strong in his feelings against the Germans.

When we reached the upstairs study he started at once quizzing me on who was who among the famous men philosophers, musicians, painters, scientists, etc., whose pictures covered the

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walls. I managed by lucky chance to do pretty well, say 50 per cent. The fact that I recognized Arrhenius and was one of his countrymen was the first friendly point of contact.

He started asking me about other scientists. Did I know Steinmetz? Did I know Einstein—that German that the Americans had so recently feted? Heaviside thought Einstein all wrong—because he felt that if Einstein were right his own writings would have to be rewritten—which is not the case. We talked of many things from war to literature, art and science. He ended our first visit by giving me two pictures of young girls. If I were fond of mathematics I must be fond of beauty and these little girls were beautiful. He went so far as to suggest that we time our watches so that he could be down stairs at 10 a.m. next day, Sunday, to open the door. And he was there—right on the minute.

He gave me permission to present him with a pipe. So I bought him two Dunhills together with the usual cleaning outfit that goes with them. This made a further topic of conversation.

That day I succeeded in discussing with him some of the difficulties that I found in reading his books. Showed him some things that I had found and wondered if he had thought of them, perhaps had published them in his collected papers which I had not seen. As a result he insisted upon my taking his only copy, for which he had been offered 500 pounds but I, of course, refused the offer. By this time he wanted to give me everything—an old original edition of Thackeray, etc.—indeed, his own photograph if he could find it and he had hunted for it—dreamed of it the previous night. I stopped at his brother's house on the way back and had a pleasant conversation with him also.

Heaviside seemed to like to write letters and I was fortunate enough to receive many, about one a week until November 16 when he had a severe accident which probably was the direct cause of his death in February, 1925.

The correspondence dealt largely with the difficulties he had with his "Bobby," the Gas Company which did not supply him enough gas to keep him warm and some shoes that I tried to find for him. His feet were in very bad shape and I tried to get him

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shoes and sent him shoes from England, France and America. The particular pair he refers to in this last letter came from America and were stamped "Five Dollars."

His last letter reads as follows:

"Home Field,
Torquay, 16.11.24

"Prof. E. J. Berg
Dear Professor,

I duly received the boots marked "5 dollars" and I think they are as near as possible without orthopedic operations; I cant remember whether I *ackd* receipt before unless it was in the Bobby letter. He is just the same, roars at me louder and louder, explains things to my stupidity, etc. as though he were trying to force a quarrel on me. I am very meek, mild, and humble of course, and also very ill again. The arrival of winter has caused Gas Co. trouble again. Hardly ever enough gas and rapid failure of the old, small mains by naphthalene and other chokage.

Worse than that I had to have some repairs done to the windows and roof slates and gutters, to keep out the wind and rain. The single man I got was most willing, but was too confident, and he was not well, though he said he was. I was quite grateful for my practical way of helping the out of works, by giving them work they *can* do, treating them liberally as well. But he didn't understand the construction of the roof (his master does mostly repairs to small workmen's houses). So I had to direct him in many respects, and be out of doors, and I had an accident. In coming down a ladder my coat caught in something, and down I went, a fall of 11 feet on to the broad of back. The man did the usual stupid thing by trying to get me on to my feet to see if I had hurt myself. I said, let me lie, till the pain in back goes. In about five minutes it was gone, and I was able to be pulled up, and actually walked indoors shakily. The pain had gone through me to the front, to the muscles and bones all the way down from the top of the chest. Well, by warmth and in bed I would cure that in a few days. But I could not get the warmth or proper food, and the window mending had to go on, so the house chilled, and the man had to be looked after. The result was a violent attack of internal derangement. . . . . The man worked hard to get the window panes mended or else puttied up if not broken. And he offered to go up and mend and put everything right on the roof

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if I would leave it to him. *I flatly refused.* That was on Thursday. That I was right was proved by a note next morning from his master, saying he had broken down and could not come. (I knew that he might in his eager excited state fall 40 feet into the yard). I replied, saying I could give him *indoor work* to do with just a little outdoor work, but he must be quite *fit* first.

I have another fight on. I order Milkmaids Pure Cream with no Preservatives. Liptons send me the common heavily sugared and adulterated tins they call "Milks." I refuse them. They try to make me take them. I wrote to Switzerland. They sent my letter to London. The London firm said they were greatly obliged to me. They were astonished to learn that Liptons didn't stock the Pure Cream Milkmaid Brand, and would do their best for me. Liptons here made a special requisition for me and got 24 Milkmaid from their London firm. With lump sugar added according to taste they are splendid, and I ordered here 48 more, with 6 pounds of lump. They sent the lump but no more Milkmaids. Yet I have to proceed cautiously. I have 167 "Milks" and I want them all taken back in exchange for "Milkmaids," and I wont pay their bill unless they will allow for difference in price; so as Xmas is coming on when business is blocked, I want a settlement quickly. I am aiming at Lipton, the largest grocer in the world, permanently stocking Pure Unadulterated goods, so pray do not send me any as I know in your kindness you might want to for they would come too late.

Yrs tr.
Oliver Heaviside."

Poor Heaviside I can see him now, his face strikingly handsome with brilliant eyes, fine teeth and a most remarkable head of hair. He was slightly stooped on account of rheumatism, his hearing was not as keen as it might be but his eyesight was perfect. He gave no impression of being an invalid. He had the gracious bearing and manners of a gentleman of the old school and was indeed the type of true scholar one is want to picture.

His home called "Homefield" was in the upper section of Torquay, overlooking the harbor. No fairer view could be found in England, and no man could better appreciate its beauty than Oliver Heaviside. It might be said that he lived a lonely life but it is really doubtful whether he ever felt lonely. A true

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artist, he was living in the garden spot of England in close communion with nature and was probably happy.

I conclude this sketch with Heaviside's idea of immortality:

"A part of us lives after us, diffused through all humanity—more or less—and through *all* nature. This is the immortality of the soul. There are large souls and small souls. The immortal soul of the 'Scienticulists' is a small affair, scarcely visible. Indeed its existence has been doubted. That of a Shakespeare or Newton is stupendously big. Such men live the best part of their lives after they are dead. Maxwell is one of these men. His soul will live and grow for long to come, and hundreds of years hence will shine as one of the bright stars of the past, whose light takes ages to reach us."

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THE FORMATIVE EFFECT OF DAY LENGTH ON WHEAT SEEDLINGS*

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INTRODUCTION

When winter wheat is planted in the fall, in regions to which it is well adapted, it lives through the winter in a dormant or resting state with no stem elongation and with the leaves appressed to the ground. The descriptive term "rosette" is used to characterize this phase of growth. In the spring, the stems elongate, the plant becomes erect and proceeds to normal heading and grain production. But when this same variety is planted in the spring it grows erect from the first without passing through the "rosette" stage, and heads abnormally, if at all. A period of dormancy or suspended development would therefore appear to be essential for the best development of winter varieties of wheat.

The question as to what growth factors of the spring environment are responsible for the continuous and abnormal growth of these varieties in spring plantings is of theoretical interest and also of practical importance. Inasmuch as it often becomes necessary to replant fields of winter wheat which have not survived a severe winter, an understanding of the critical factors involved might permit accurate determination of the latest date when planting with a winter variety in any given locality could be safely recommended.

The spring environment is characterized both by increasing temperatures and by increasing day lengths. It is well known that high temperatures will produce abnormal growth of winter wheat (16, 17, etc.). But the failure of the rosette habit to

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develop in spring plantings in a greenhouse having temperatures held constantly below 20°C., where the rosette habit was found to be characteristic of winter plantings, suggested day length as a decisive factor.

The classic researches of Garner and Allard (9, 10) have revealed the fundamental significance of day length as a formative factor in the growth of many plants. They showed (11), in contradistinction to Kleb's (13) emphasis on the importance of total quantity of light, that the critical factor is the length of the period of continuous illumination irrespective, within wide limits, of the total light energy received. Their work on cereal plants (10) showed that, in general, increasing the length of the daily light period by electric illumination (3 to 5-foot candles) from sunset to midnight had a marked effect on the height, number of tillers, and dates of heading of spring and winter varieties of wheat, rye, oats, and barley. They emphasize the greater responsiveness of the spring types to increased day length as compared to that of the winter types. In the case of spring wheat, for instance, the long-day plants were much shorter at maturity, had but one-third as many tillers, and matured much more rapidly, than did the plants subjected to a normal day length.

These effects of day length on the growth and maturation of wheat have been confirmed by a number of investigators (1–6, 12, 14, 15, 19). Of special interest is the brief report of Wanser (18) who noted that by regulation of the daily exposure to light, jointing (the stage of stem elongation) and heading of winter wheat could be induced irrespective of season, the response being alterable, however, by temperature and nutritional factors. The details of the observations on which these conclusions were based have not been published.

The present report has to do with the formative effect of day length under controlled temperature conditions on the first growth stage of a winter wheat (Turkey). A spring wheat, Hard Federation, which differs physiologically from the winter wheat in not responding to winter conditions with a dormant or resting period, was included also for comparison.

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METHODS

The plants were grown in greenhouses having automatically controlled temperatures. The low-temperature house was kept at 10° to 12°C., and the high temperature house at 20° to 23°, except for a few hours on sunny afternoons when it rose about 10° in each house. These temperatures were maintained by a blower and distributing system which drew in cold outside air under the control of a thermostat. On warm afternoons, when the outside air was not cold enough to permit effective control, a sprinkeler system on the roof of the low-temperature house kept the inside temperatures lower than those in the high temperature house by about 7°C. Soil temperatures were 8° to 10°C. in the low-temperature house, rising occasionally on warm afternoons to 15°. In the high temperature house they were kept between 18° and 20°.

On one of the four parallel benches in each house were grown the control plants with natural day length. For the plants on a second bench the day length was reduced to eight hours by means of a light-tight cover of closely woven black sateen. This cover, supported on a framework, was drawn over the plants every day at 4 p.m., and removed the next morning at 8 a.m. For the plants on the third bench the natural day length was supplemented each day by artificial light from 500-Watt Mazda-C electric lamps in deep bowl reflectors, suspended above the bench 2½ feet apart. These lights were turned on each day from 4 p.m. till midnight. The distance of the plants in this bench from the lights directly above them was a little more than 4 feet at emergence. At this distance the light intensity, as determined with a Halophane illuminometer, was a little over 100 foot-candles. In the corners of the bench farthest from the lights it was only about 50 foot-candles.

To determine the importance of a difference in light intensity, identical plantings were made in an adjacent fourth bench having no lights directly over it, but illuminated from the side by the lights over the third bench. On this fourth bench the intensity ranged from approximately 50 foot-candles, on the side nearest the lights, to as low as 15 foot-candles on the opposite side.

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The radiant energy from the lights was sufficient to raise the temperature, as recorded by the thermograph placed at the level of the plants directly beneath the lights, by 1°C. in the low temperature house and by nearly 2° in the high temperature house. In the fourth bench with the reduced light intensity, the increase in air temperature due to the lights over the adjacent bench was but 0.5°. There was no appreciable increase in soil temperature at the level of the roots in any case.

The plants in the control bench were protected from the artificial illumination by a heavy sateen curtain which was kept in place only when the lights were on. The short-day plants were protected by the box covering which prevented any light reaching them between the hours of 4 p.m. and 8 a.m.

RESULTS

It was found in the first experiment that winter wheat, sown on December 13 in the low-temperature house, assumed the rosette habit characteristic of fall-sown wheat of this variety in both the control bench having the natural light period of 9½ hours and in the bench given the short (8-hour) day. The long-day plants under the lights maintained from the first the erect growth habit of spring-sown winter wheat, in striking contrast to the flattened appearance of the plants with the shorter day lengths. In spite of the considerable gradient in light intensity (15 to 100-foot candles approximately) to which the plants in the two long-day benches were subjected, they were much alike in appearance and development; so the effects of additional illumination of above 15 foot-candles are apparently independent of the intensity of the light. In the warm house (20° to 23°) in which the temperatures were unfavorable for the development of winter wheat, rosetting did not appear at any day length, indicating a close interrelationship of the temperature factor. An interrelationship of temperature with day length responses has been noted by Garner and Allard (9, 10), Adams (1, 3), and Gilbert (7, 8).

It is of interest to note that although the short day initiated rosetting in the low-temperature plants, it could not maintain it through a week of very warm weather in early February which

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prevented temperature control. The air temperatures rose above 30° each day for several successive days, and the soil temperatures rose to about 20°. Shortly thereafter the natural-day plants started to grow vigorously and were followed about two weeks later by the short-day plants. Soon they were all erect and greatly changed in appearance. It is assumed that the period of high temperatures was responsible for this change inasmuch as the day length remained unchanged. So it was impossible to determine whether under a constant low-temperature, short-day

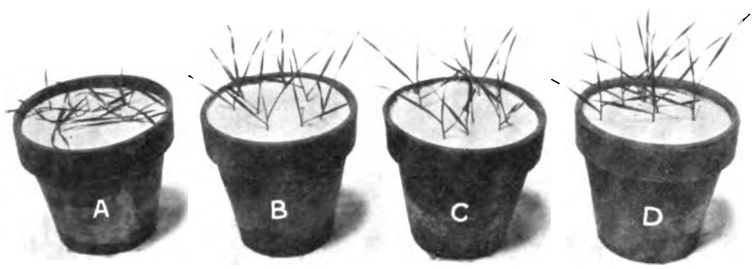

FIG. 1. EFFECTS OF DIFFERENT DAY LENGTHS ON THE GROWTH HABIT OF WINTER-WHEAT SEEDLINGS AT 10° TO 12°C.

A, short day—8 hours; *B*, natural day—12 hours, approximately; *C*, long day—18 hours, 50 to 100 foot-candles; D, long day—18 hours, 15 to 50 foot-candles.

environment, the winter growth habit would be maintained indefinitely, or whether it would be overcome by an inherent periodicity.

The observation was made that those plants growing on the outer edges of the benches where the soil always dried out more rapidly than elsewhere were much slower in breaking the rest period, remaining distinctly flattened for weeks after those not in these areas were erect.

This experiment showed, then, that at the more favorable temperature for normal growth (10° to 12°) the resting stage was produced by both the 8- and 9½-hour (natural) light periods, but

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prevented by a 16½-hour light-period. The inhibiting effect of the long day was just as pronounced in the bench with the day length supplemented by light of low intensity, and where there was almost no heating effect, as it was in the bench directly under the lights. The temperature interrelation shown by the inability of the plants in the high-temperature house to become dormant at even the 8-hour day suggests the possibility that at tempera-

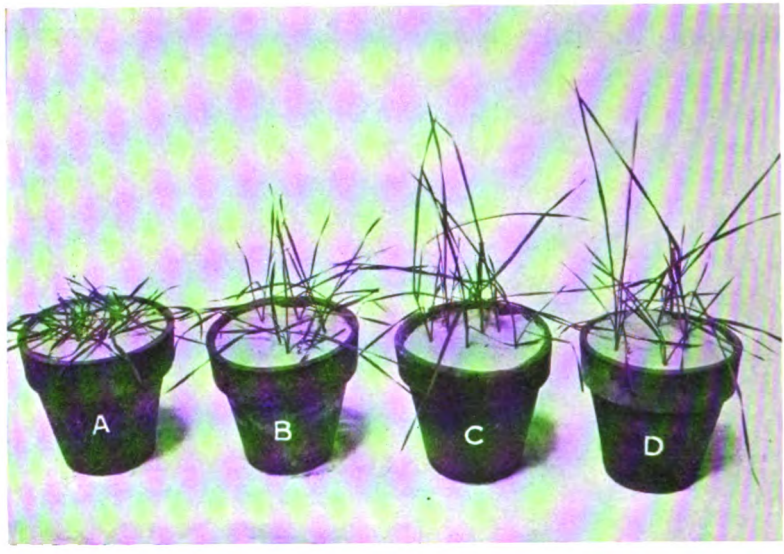

FIG. 2. EFFECTS OF DIFFERENT DAY LENGTHS ON THE GROWTH HABIT OF WINTER-WHEAT SEEDLINGS AT 20° TO 23°C.

A, short day—8 hours; *B*, natural day—12 hours, approximately; *C*, long day—18 hours, 50 to 100 foot-candles; *D*, long day—18 hours, 15 to 50 foot-candles.

tures lower than those in the cold house (10° to 12°) dormancy might occur with a long day.

Spring plantings of these same varieties were made on February 25, when the natural duration of day light was 11½ hours. The temperatures remained controlled as before with the exception of occasional warm afternoons. The seed was sown in 6-inch pots, filled with some of the same soil that was used for the benches in the first planting. After planting, the surface of the

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soil was covered with white sand to facilitate photographing the plants. The pots were placed on the benches beside the plants of the winter sowing. Their appearance at the age of one month is shown in figures 1 to 4 by representative plants of each group.

In this experiment the control plants at the low temperature (fig. 1, *B*), unlike those of the winter sowings at the same temperature, grew erect in the manner of spring-sown winter wheat plants. The only rosetting occurred with the artificially short-

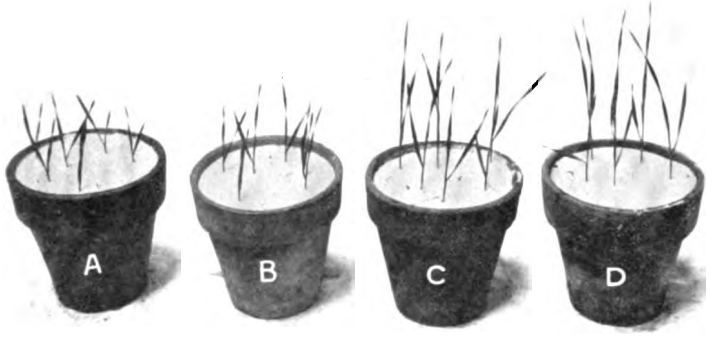

FIG. 3. EFFECT OF DIFFERENT DAY LENGTHS ON THE GROWTH OF SPRING-WHEAT SEEDLINGS AT 10° TO 12°C.

A, short day—8 hours; *B*, natural day—12 hours, approximately; *C*, long day—18 hours, 50 to 100 foot-candles; *D*, long day—18 hours, 15 to 50 foot-candles.

ened day (fig. 1, *A*). Since the temperatures during this early growth period were not appreciably different from those of the previous winter sowing of this same variety, it seemed that this failure of the winter habit to appear in the low-temperature control bench was due to the lengthened days of spring. During the month that these plants had grown, the day length had increased from $11\frac{1}{2}$ to $12\frac{1}{2}$ hours. The approximate day length during the first month of growth of the winter planting, in which rosetting had occurred in this bench, was $9\frac{1}{2}$ hours. Thus the critical light

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period at this temperature is somewhere between $9\frac{1}{2}$ and about 12 hours.

In the previous experiment none of the high temperature plants (20° to 23°) had shown this winter growth habit, not even those with the 8-hour day. But figure 2, *A*, shows that the high temperature did not inhibit dormancy in the 8-hour-day plants of this second experiment. Growth conditions of these short-day

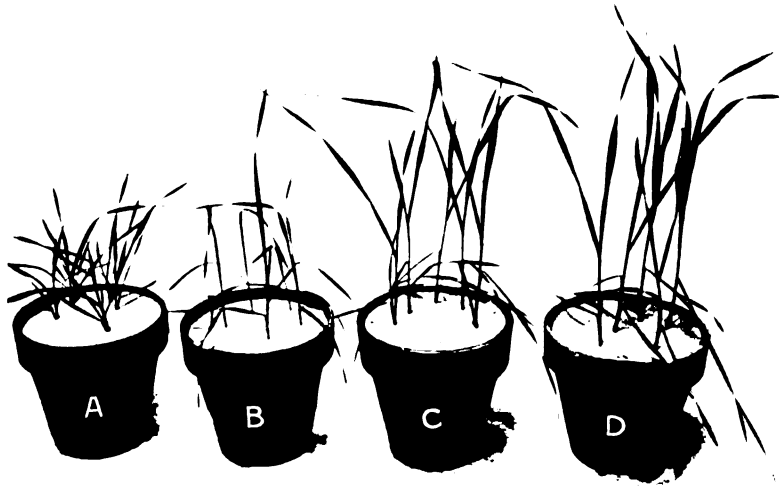

FIG. 4. EFFECT OF DIFFERENT DAY LENGTHS ON THE GROWTH OF SPRING-WHEAT SEEDLINGS AT 20° TO 23°C.

A, short day—8 hours; *B*, natural day—12 hours, approximately; *C*, long day—18 hours, 50 to 100 foot-candles; *D*, long day—18 hours, 15 to 50 foot-candles.

plants in the two experiments differed in that the plants of the first experiment were grown in deep soil in the greenhouse benches, those of the second in pots set on the soil in these benches. A temperature as high as 20°C. is apparently near the critical temperature for the "rosette" growth response of this variety, and at temperatures of this magnitude, the response can probably be easily affected by other environmental factors such as soil moisture or soil aeration. It had been observed in connection

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with the winter planting that with the onset of the warm weather which stimulated most of the plants to active growth the rosette period was prolonged for several weeks in portions of the short-day bench where the soil was frequently drier than in other portions of the bench. Since the soil in the pots may be expected to have dried out faster than that in the benches, the suggestion appears from both these observations that low soil moisture contributes to the "rosette" tendency, and at the critical temperature may be a determining factor.

This suggestion recalls Wanser's (18) observation that the response of winter wheat to day length may be altered by temperature and by nutritional factors—although elsewhere he states that this response is independent of temperature. The idea that soil factors may become more potent at a critical temperature is consistent with the assumption that a growth response is always the result of an internal chemical organization which may be affected to some degree by all the growth factors in the environment.

Figures 3 and 4 show the effects of the different light-periods on a spring wheat, Hard Federation, which does not assume the rosette growth habit under any conditions so far as known. At both the low and the high temperatures the artificially lengthened day markedly increased the rate of growth, and the shorter light-period decreased it. Figure 4, *A*, illustrates the stimulating effect of the short day on tiller production, an effect which agrees with the reports of previous investigators that increased day length reduces tillering in spring varieties.

The rate of development of Hard Federation was more retarded by the low temperature than was that of the winter wheat, as shown by the fact that the plants in figure 3 were in the 2-leaf stage, whereas the corresponding low-temperature plants of the winter variety in figure 1 were in the 3-leaf stage.

In this, as in the previous experiment, the long-day plants of each variety growing directly under the lights were indistinguishable from those growing in the bench several feet to one side. So increasing the light intensity above 15 foot-candles, the intensity prevailing in the most distant corner of the bench

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farthest from the lights, has no appreciable effect on the response of the plants to the long light-period.

The situation with respect to the action of the day length factor in these experiments may be summed up by saying that a winter variety grown with a short day (both 8 and 9½ hours), and below

FIG. 5. EFFECT OF DORMANCY IN AN EARLY STAGE ON SUBSEQUENT DEVELOPMENT OF WINTER WHEAT

The plants are all 14 weeks old and are being subjected to a long (16 to 18 hour) day at 10 to 12°C. Those to the left showing abnormal development had been grown in this bench under these conditions throughout, and consequently, had had no resting stage. Those to the right were transplanted, after eight weeks, from the bench having short daily light-periods which had induced the normal resting stage. They began active growth within a few days after being transplanted to their present location and have surpassed in height and stage of development the plants which had grown continuously under the long-day conditions.

a certain critical temperature (near 20°C.) develops, in the early vegetative period, the normal rosette habit. The type of response near the critical temperature seems to be influenced by soil conditions. Thus under favorable temperature conditions winter plantings rosetted at the natural day length (9½ hours or less), and were prevented from doing so by artificially increasing the

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day length to 16½ hours. Spring plantings failed to rosette at the natural day length (11½ to 12½ hours), but were induced to do so by artificially shortening the day to 8 hours to simulate the winter condition.

The importance of the resting or rosette stage for the subsequent normal development of winter wheat is suggested by the photograph in figure 5, taken on March 25. These plants were all of the winter sowing of December 13, and, when photographed, were growing at the low temperature and the long day. Those at the right were transplanted on February 11 from the short-day bench, where they had been for two months in the procumbent, dormant stage. Those at the left had the long light-periods from the first, and, consequently, were never in the rosette stage. Within a few days after being transplanted to the long-day bench, the rest period of the short-day plants was broken, and they began to grow rapidly. The photograph shows them in the jointing stage with their stems elongated preparatory to head production, whereas the development of the adjacent long-day plants is arrested in the tillering stage, as is typical of the growth of this variety in spring plantings. It does not seem probable that the more rapid development of the short-day plants was the result of transplanting. So the visible formative effects of light in early stages seemed associated with physiological conditions of fundamental importance to subsequent development.

CONCLUSIONS

These experiments have demonstrated the importance of a short day for the initiation of the "rosette" growth habit in fall-sown winter-wheat plants, and have given evidence of the interrelationship of this factor with temperature and some soil condition, apparently moisture supply. This resting period, if not essential, is at least conducive to the subsequent normal growth and maturation of the plants.

The writer is much indebted to Mr. H. A. Allard of the Bureau of Plant Industry of the United States Department of Agriculture for his helpful suggestions during the course of these experiments.

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NECROLOGY

Mrs. William Wagner Mrs. Ida Mae Waters

OBITUARY

MRS. WILLIAM WAGNER (CLARA APPLETON WAGNER)

Mrs. Wagner died suddenly and peacefully on February 27 after an eventful life of over eighty-seven years.

Born in Philadelphia of the Quaker families of Appleton and Shoemaker, she carried the Quaker qualities of spirit and conduct throughout her life, although in early womanhood she became a member of the Episcopal Church.

It was at about this time that the young women of the nation were called upon for their part in providing for the troops engaged in the great Civil War struggle and this was brought painfully close to her, due to her engagement to Mr. Wagner, which occurred as he was leaving for the front as a major of cavalry.

Immediately following the War and her marriage she entered into a frontier life of many unique experiences with her husband who became engaged in the building and operation of railroads in Colorado.

Mrs. Wagner's only child is her son, Herbert A. Wagner, at whose home in the Green Spring Valley near Baltimore she spent the last twelve years of her life. Prior to that she lived for many years in New York City, where she was intimately engaged in charitable and literary work, being a director and official of the New York Diet Kitchen, the Wednesday Afternoon Club and other clubs.

Until the day of her death she remained physically active and mentally interested in all the topics of the day.

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THERMOCOUPLE FOR MEASURING INTERNAL BODY TEMPERATURES OF ANIMALS*†

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Research Department, Consolidated Gas Electric Light and Power Company, Baltimore, Maryland

In an investigation of the effect of elevated temperatures on tumors in white rats, Dr. George Walker (1) found it difficult to heat the body of the animal to a sufficiently high temperature to destroy the tumor without effects which resulted eventually in the death of the animal. He expected such difficulty, because the thermal death point of tumor tissue appears to be less than that of normal tissue by no more than a few degrees. This temperature difference between the death points of the tissues is by no means definitely established. However, the temperatures in various parts of the animal after treatment were not known. Consequently, it was not known whether the animal died from an overheating of all parts of the body, or from the local overheating of some tissue or organ. The possibility of controlling local heating, if it existed, presented itself as a method of aiding the animal to successfully withstand the treatment. The present work had its origin in the investigation of this possibility. Aside from its bearing on the problem of tumor treatment, however, the production of local high temperature in the body with its accompanying phenomena has physiological interest.

That temperature differences exist between various parts of the body of a normal animal, has been known for a long time (2, 3), and these differences have been the subject of considerable speculation, observation and experimentation for over one hundred years. Indeed, about the middle of the last century, the medical

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† Extract from report given before the Medical Section of the Maryland Academy of Sciences, May 22, 1930.

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profession was divided on the question as to whether the venous or the arterial blood was the warmer, a question considered to be of great importance for the discovery of the source of animal heat. Many of the leading scientists of the time, including Lavoisier, Lagrange, Magnus, Gay-Lussac, Berthelot and Liebig, were interested in this question. Since the time of Claude Bernard, it has gradually been accepted as a fact that the venous blood is the warmer. The work of Bernard (4) on the temperature difference between the arterial and venous blood in various parts of the body showed, moreover, that the arterial blood was heated in its passage through any organ, the lung being the only exception noted. In this case, the blood supplied to the organ was actually cooled in passing through it. The absence of the heating effect was accounted for by assuming that the cooling of the blood due to the process of breathing was greater than the heating of the blood due to the chemical activity of the lung.

Although the effects of various factors on the distribution of temperature in a normal animal have been investigated, and although considerable work has been done on fevers, the data are only indirectly applicable to the problem of heating by high frequency electrical oscillations (diathermy), one of the methods of heating used in this investigation. For the purpose of making such temperature explorations in both normal and heated animals under conditions which would give comparable results, it was necessary to construct special needle thermocouples for measuring internal temperature differences. The use of thermocouples in determining the temperature of various parts of animals and man is not new, as is shown by the historical facts given below which indicate the principal developments only.[1]

About 1820, Seebeck (5) discovered that an electrical current was produced in a circuit consisting of two dissimilar metals joined together when the two junctions were kept at different temperatures. This effect was early used to determine temperature differences between the two junctions of such a circuit. The combination of the two metals is referred to as a "thermocouple."

[1] Woodhead and Varrier-Jones, (18), give a review of clinical temperature measurements which includes the use of thermocouples up to 1916.

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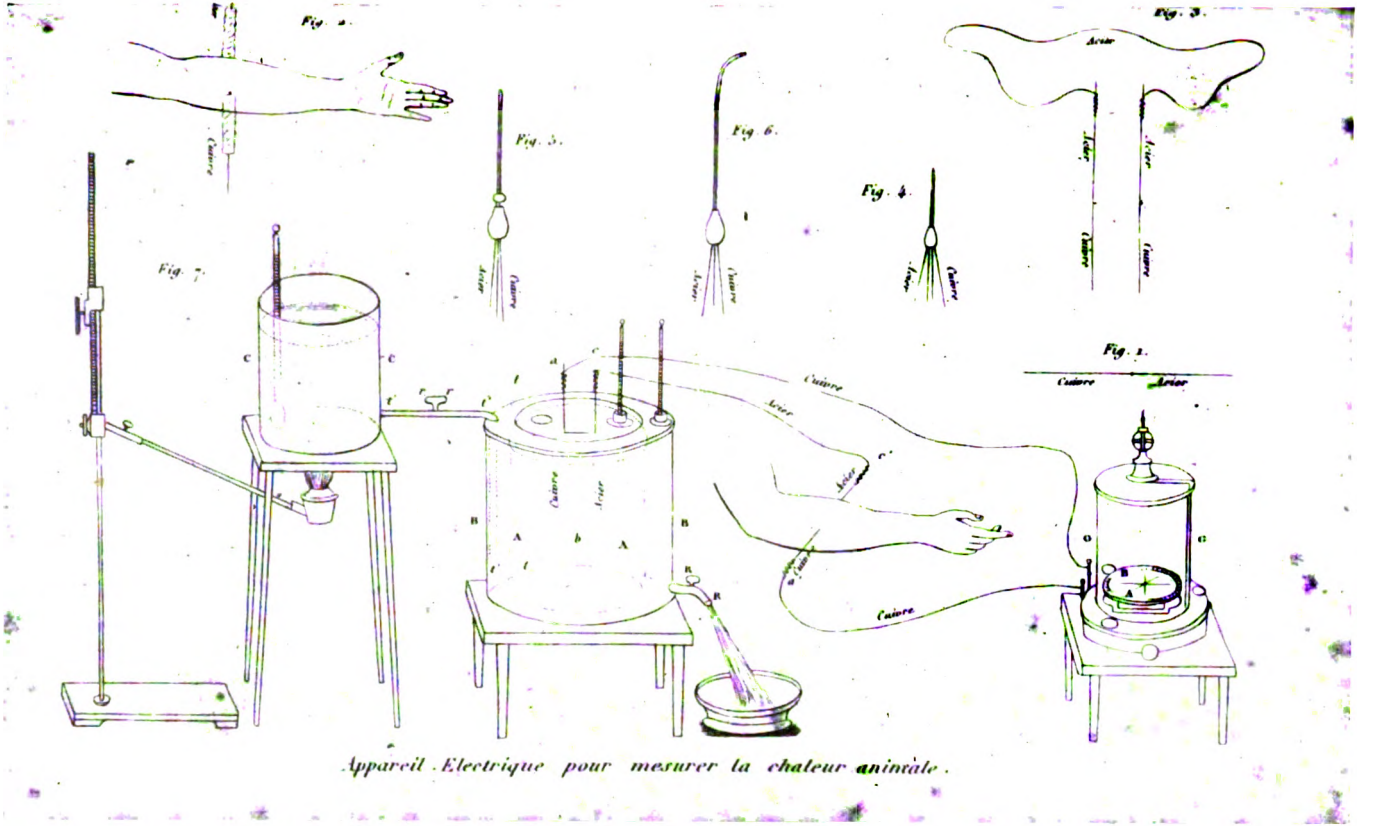

FIG. 1. REPRODUCTION OF APPARATUS OF BECQUEREL AND BRESCHET
Annales des Sciences Naturelles, Seconde Série, Tome Troisième, Zoologie, 1835, pg. 257, Planche 9

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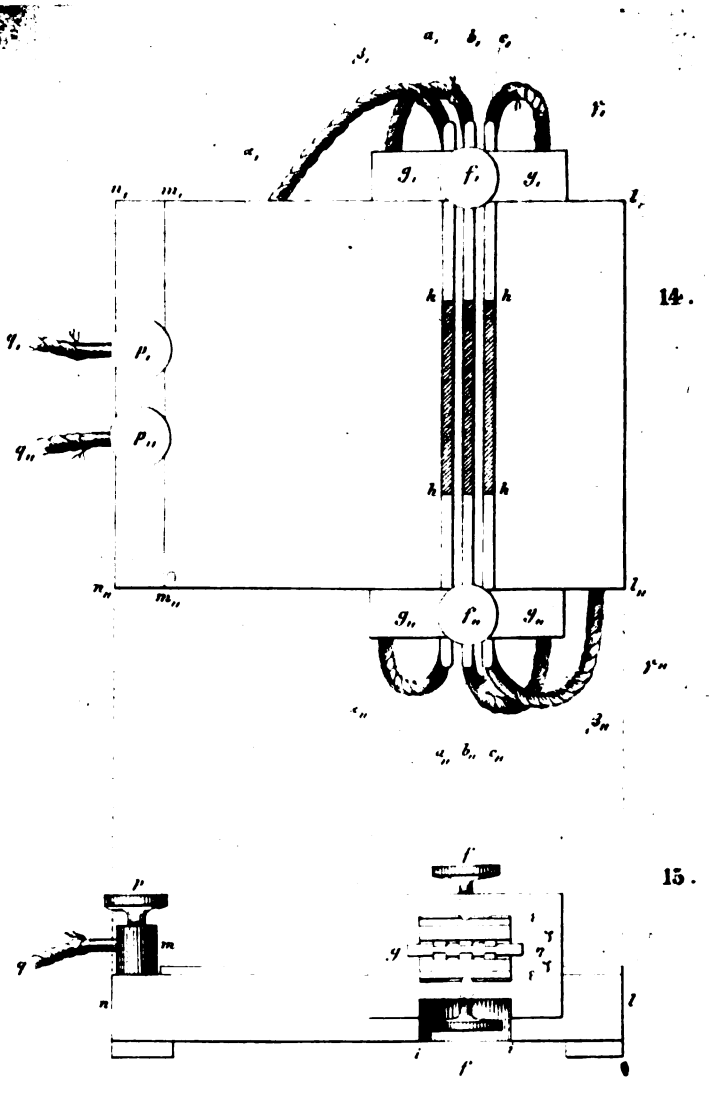

FIG. 2. REPRODUCTION OF APPARATUS OF HELMHOLTZ
Müller's Arch. für Ant. und Physiol. 1848 pg. 144, Taf. VI

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About fifteen years later, Becquerel and Breschet (6) described for the first time the use of such thermocouples for exploring temperature differences in the animal body, although mercurial thermometers had been used for this purpose earlier. The sketch

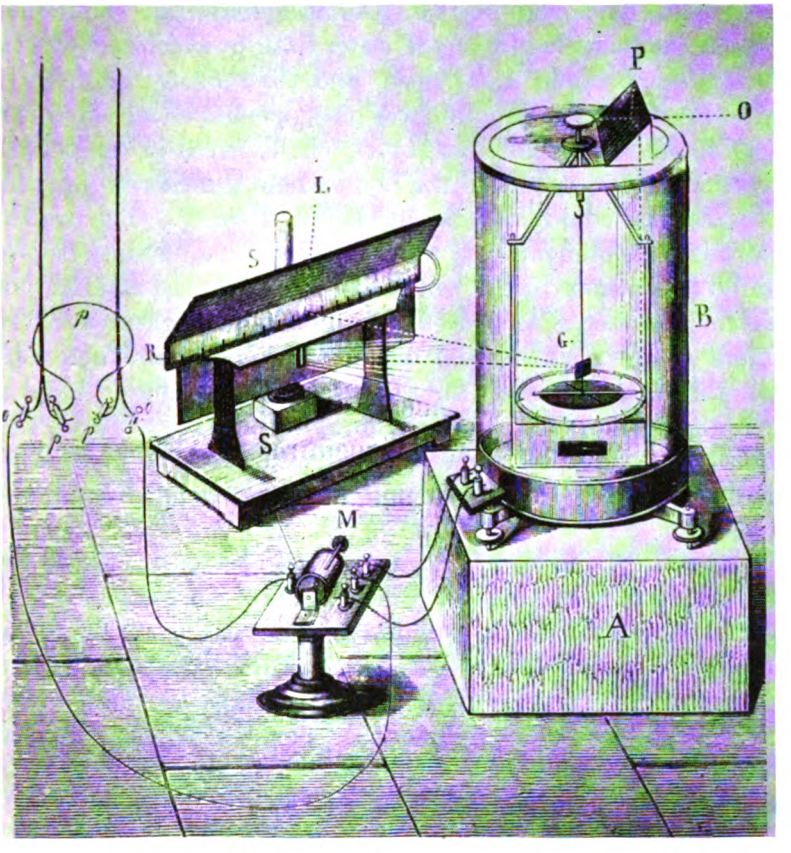

FIG. 3. REPRODUCTION OF APPARATUS OF BERNARD
C. Bernard, "La Chaleur Animale," Paris 1876 pg. 73

of the apparatus as given by them is reproduced in figure 1. The thermocouples constructed in various forms as indicated in the reproduction consisted of copper and iron wires having a diameter of 0.5 mm.

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In the forms shown in figures 4, 5 and 6 of the reproduction, the wires were separated by a piece of quill and covered with a plastic cement which served not only to hold the wires together, but also as an insulating coating. Apparently, the form which consisted of straight wires joined end to end (fig. 3 of the reproduction) was not covered with an insulating material. Differences between the temperature of the water bath in which one junction of the thermocouple was placed, and that of any point in the body where the other junction was placed, could be measured with a galvanometer to less than 0.1°C. Differences in temperature between any two points in the body where the thermo-junctions were inserted could also be measured directly. The authors reported measurements on the temperature difference between arterial and venous blood, which indicated that the arterial blood was the warmer. Measurement of the temperatures of two tumors of the neck showed one to be warmer and one colder than the mouth, while a breast cancer was found to have the same temperature as that of the mouth. The work of these pioneers as well as of some who followed them is not entirely reliable because the thermocouple wires were inadequately insulated.

Helmholtz (7), in 1848, using thermocouples for measuring temperature differences between contracted and relaxed muscles, was able to show that the contracted muscle was the warmer, and moreover, that this temperature difference increased with the number of contractions of the muscle. However, he could not detect a difference of temperature between a stimulated and unstimulated nerve with this apparatus. His sketch of the thermocouples and mounting is reproduced in figure 2. The thermocouples consisted of three thin iron strips, to the ends of which German silver strips were soldered. These were arranged parallel to each other in a plane, and connected together so that the thermo-electromotive forces at all the junctions would cause a current to flow in the same direction, thus increasing the sensitivity of the apparatus. The unstimulated muscles could be placed across one set of three junctions and the stimulated muscle across the other three junctions. The resulting temperature dif-

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ference between the two sets of junctions could be measured to within 0.001°C. by means of a sensitive galvanometer.

By means of an improved thermopile, or series of thermocouples, of antimony and bismuth, Schiff (15) was able to show that irritation of a nerve increases its temperature, and also that the temperature of the cerebrum is increased by simple and complex stimuli.

In a series of lectures published in 1876, Claude Bernard (4) gave a critical review of work which had been done up to his time on temperatures in various parts of the body, but discussed particularly the temperature difference between venous and arterial blood. He showed that experimental results on this latter question had been very conflicting. By means of thermocouples and a sensitive galvanometer, figure 3, he claimed to have shown conclusively that the venous blood was warmer than the arterial blood. These thermocouples consisted of copper and iron wires. The soldered thermo-junction was placed in a small rubber tube closed at one end. This tube, not shown in figure 3, served as an electrical insulating sheath, and made it possible to determine temperature differences between the two junctions when they were immersed in such a conducting medium as the blood. An incision had to be made when sub-surface temperatures were measured.

Heidenhain and Körner (8) by similar thermocouple measurements on the temperature difference between venous and arterial blood obtained results in agreement with those of Bernard.

Lefevre (9) described and used a thermocouple which could be inserted directly into the tissue as it was provided with a sharp needle point at the thermo-junction. It consisted of an insulated German silver wire inserted in a small bore iron tube, one end of which was turned down to the size of a hypodermic needle, the other end being threaded into an ebonite sheath which served to shield the needle from air currents and to fix the depth of penetration of the needle. The needle was covered with an insulating varnish to eliminate electrochemical effects. The thermo-electric circuit contained only iron and German silver wires up to the galvanometer terminals. Connectors of the same material as

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that of the wires were used wherever necessary. With this precaution, it was expected that all thermal effects would be eliminated except those at the junctions between the iron and German silver wires.

Macleod, Self and Taylor (16) used a copper constantan couple, whose junctions were inserted into hypodermic needles, the points of which were closed with solder. The wires were twisted together at the junctions and insulated with shellac. Temperature differences between the tissues and the skin were measured with this apparatus.

Crile, Hosmer and Rowland (17) used a copper constantan thermocouple to measure internal temperature of the brain and other organs during stimulation and exhaustion from various causes. The metal junction of their couple was exposed to the tissue to make good thermal contact with it. The wires, (0.005 inch in diameter) were insulated with small glass tubes.

Adrian and Watts (10) described a thermocouple for exploring body temperatures, which consisted of a No. 24 hypodermic needle into which was placed an insulated No. 30 constantan wire soldered to the needle at the beveled end. An iron wire was soldered to the needle near its base, so that the steel needle formed a part of the thermo-electric circuit. Bazett and McGlone (11) pointed out that since the junction between the steel hypodermic needle and the iron wire was the seat of an electromotive force, errors would be introduced in the temperature measurements if the junction were not kept at a constant temperature. They described a modified form of thermocouple in which this effect was eliminated by substituting for the iron wire a steel tube of the same quality as that of the hypodermic needle. They also discussed in detail errors which arise from the conduction of heat along the needle, and showed the necessity of using small needles. A thermal insulating sheath similar to that described by Lefevre (9) was used over that part of the needle exposed to the air to reduce effects of air temperature.

Several forms of thermocouples have been described for measuring surface temperatures. Lewis (12) used a copper constantan couple in which a silver plate was attached to the junction for the

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purpose of improving the thermal contact with the surface of the skin. Lefevre (9) improved the contact of the thermo-junction with the skin in a similar manner, but used instead of the silver disk, one having a central area of iron surrounded by an annulus of German silver, the circle of contact between these serving as the thermo-junction. Benedict (13) used a conveniently mounted copper constantan couple for measuring skin temperatures, and took special precautions to eliminate heat loss from the point of the skin at which the thermo-junction was applied by covering the junction on the side removed from the skin with a cotton pad. Scott (14) used several thermo-junc-

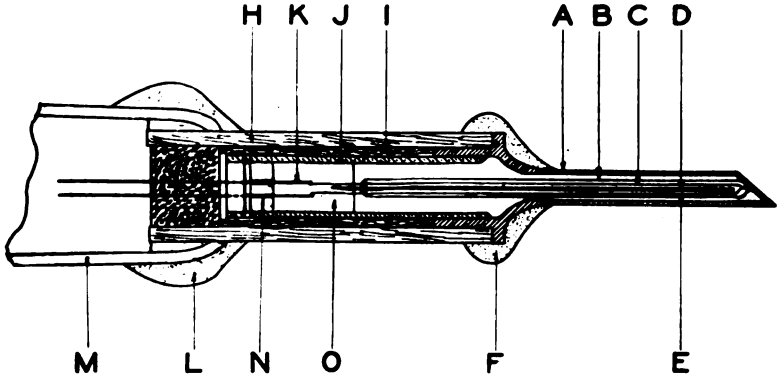

FIG. 4. DIAGRAM OF HYPODERMIC NEEDLE THERMOCOUPLE JUNCTION

tions in series as Helmholtz (7) had done to increase the sensitivity of the instrument designed to measure surface temperatures.

The apparatus described in this paper differs from the various types described by previous workers only in details of construction which appear to present some advantages. The electrical circuit is insulated so that measurements taken between two points where the junctions are introduced into the animal can not be influenced either by electrochemical action of the body fluids on the needles, or by the electrical resistance of the body between the two points. A thin walled glass tube, *B* (fig. 4), sealed at one end, serves to insulate the wires from the walls of

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the hypodermic needle, *A*. It is inserted in the needle so that the end which has been drawn down and sealed is flush with the beveled point of the needle. The needle is closed by a small amount of solder which adheres closely to the glass tube and makes thermal contact between it and the needle point. The constantan wire, *E*, and the iron wire, *C*, are insulated from each other by a glass rod, *D*, to which they are cemented with dilute cellulose lacquer. The glass rod is of approximately the same diameter as the wires. Thus a glass tube of slightly over 0.003-inch internal diameter will accommodate this rod and the two wires, each 0.001 inch in diameter, if they are perfectly straight. Tubes with wall thickness of 0.001 inch or less can be readily made, so that a hypodermic needle with a bore of over 0.005 inch can be used with a glass tube and wires of this size. Hypodermic needles of various sizes have been used, but in all cases, heat conduction from the thermo-junction along the needle is reduced by grinding the needle wall down to a thickness of less than 0.002 inch for a distance of at least 0.25 inch from the point. Usually, the inside surface of the needle is rough. However, it can be smoothed out by pulling a wire covered with fine carborundum dust back and forth through the needle rotated very rapidly in a jeweler's lathe.

The wires, after being pushed into the glass tube so that the welded junction rests firmly on the sealed end, are cemented to the tube with a small amount of shellac or DeKhotinsky cement applied to its open end. The ends of the wires are anchored to a piece of fiber, *O*, held in the copper trough, *J*, which is soldered to the brass needle base. The trough is one-half of a small copper tube about 2 inches long sawed longitudinally into two parts. The leads, *K*, of constantan and iron wires, larger than those in the needles, are securely anchored in a fiber plug, *N*, which is firmly attached to the copper trough. The fine wires are connected to the corresponding lead wires by looping their ends over the bent ends of the leads and applying a small amount of solder. In order that no appreciable temperature difference can exist between these soldered junctions they are placed close together, but electrically insulated from each other by DeKhotinsky

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cement. By covering the wires with the other half of the copper tube, the junctions are further protected from the heat of the hand when the thermocouple is handled. The two parts of the split copper tube are held together on one end by the needle base, and on the other end by a brass ring not shown in figure 4. A glass tube, *H*, which is cemented to the needle base with DeKhotinsky cement, *F*, and surrounds the copper tube, serves as a handle. The space between the copper and glass tubes is partly filled with paper, *I*. The leads are insulated from each other by small tubes of rubber or varnished cambric and are enclosed in a rubber tube, *M*, cemented to the glass tube with DeKhotinsky cement, *L*.

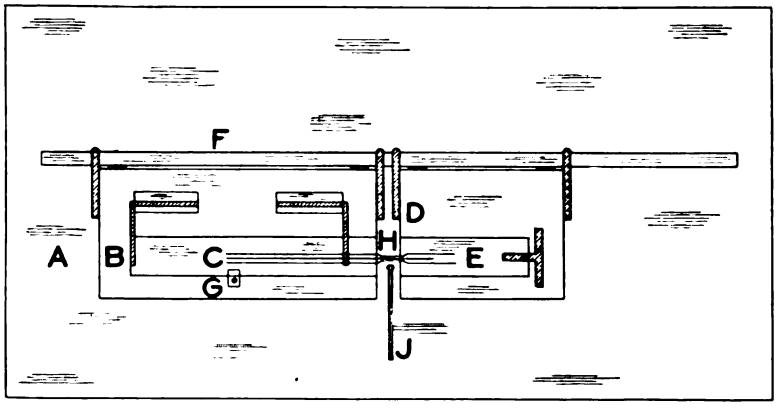

FIG. 5. DIAGRAM OF HOLDER FOR INSULATING WIRES

The wires used in the construction of the needle junction are straightened by heating them in a glass tube containing hydrogen to prevent their oxidation. The wire, stretched by a small weight, is suspended in a glass tube held in a vertical position and heated with a Bunsen flame to the annealing point of the metal.

A convenient scheme for holding the pieces of straightened wire while they are being insulated is shown in figure 5. The glass rod insulator is placed between the constantan and iron wires on the glass plates, *B* and *D*. The two wires and rod are held on *D* by allowing the hinged plate glass, *E*, to rest on them. The distance between the hinged glass cover, *C*, and the plate, *B*, is

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adjusted by the screw, *G*, so that the wires can move freely but can not cross one another. When the dilute cellulose lacquer is applied at *H* the wires and rod are pulled close together and cemented in a coplaner position. A new section of the wires is exposed for cementing by sliding the glass plate *B* or *D* on the plate, *A*, along the guide, *F*. With this procedure it is possible to prepare the wires without lacquering the ends which are to be welded or the ends which are to be soldered.

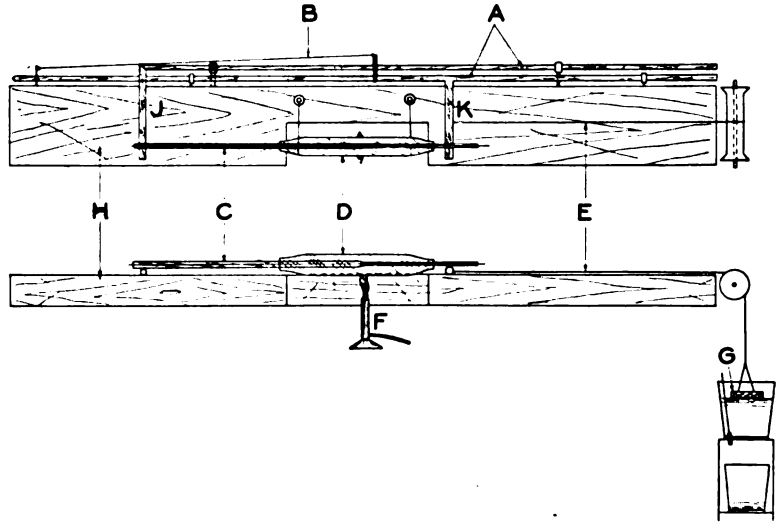

FIG. 6. DIAGRAM OF APPARATUS FOR DRAWING GLASS TUBES AND RODS

Although it is possible to make the glass insulating tubes and rods by drawing out larger tubes and rods in a free hand fashion, the apparatus shown in figure 6 gives some control of the process. The small tube or rod, *C*, to be drawn down, is passed through the quartz tube, *D*, and fastened to the sliding glass tubes *J* and *K*. It is heated to the softening point by the small Bunsen flame, *F*. applied to the outside of the quartz tube, and drawn out by pulling on the slide *K*. The sliding tubes *J* and *K* are connected together by the rubber band *B*, one end of which is anchored to the wood base *H*. Their relative motion, produced by the stretching of the rubber band when it is pulled at *K*, is deter-

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mined by the point at which J is fastened to the band. To obtain a uniform motion of K, it is attached by means of a string, E, to the float, G, which moves downward as the water in the container is allowed to run out. When the temperature of the small quartz furnace and the motion of the float are properly adjusted, the relative motion of J and K determines the change in the diameter of the tube or rod, C, as it passes through the furnace.

With this apparatus, it is possible to cover the fine wires with a very thin layer of glass which serves as insulation in place of the

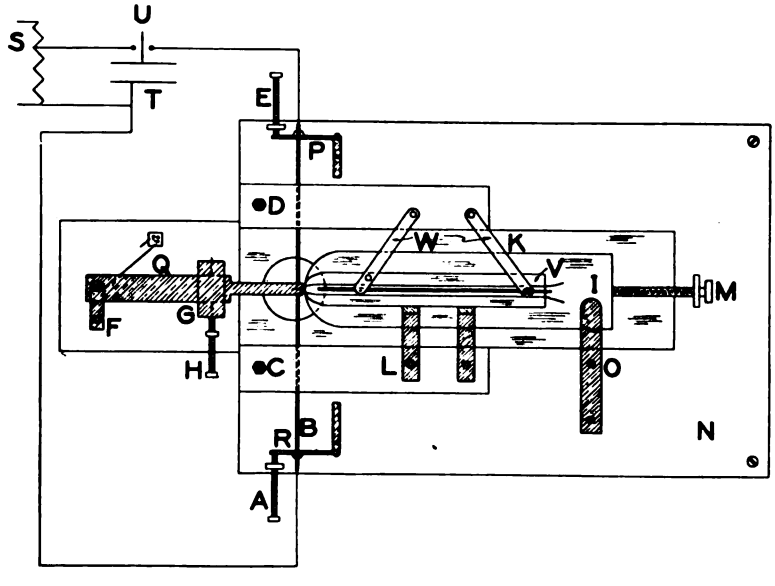

FIG. 7. DIAGRAM OF WELDING APPARATUS

glass rod described above. However, this method of insulating the wire is not as convenient as that actually used.

The small constantan and iron wires are readily welded to form the thermo-junction by the device shown in figure 7. The ends to be welded together are clamped between the copper electrodes P and B, and fused together by discharging the charged condenser, T, through them by the switch, U. As the wires must be aligned to within a fraction of their diameters, they are firmly held

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on the glass plate, *I*, by the cover glass, *V*, and clamps, *W*, while the adjustments are made. The electrodes are moved vertically by bending their hard rubber supports by the screws *D* and *C*. They are moved horizontally by bending the springs to which the electrodes are fastened, by the screws *A* and *E*. The glass plate, *I*, clamped and guided by *O* and *L*, can be moved over the plate, *K*, on which it rests, by the screw, *M*. By means of a small probe on the end of *Q*, the wires can be separately displaced in a vertical direction. This probe is moved up or down by the screw near *F*, while lateral motion is obtained through the screw *H*, which merely presses against the brass rectangle, *G*, in which the lever, *Q*, is pivoted. The adjustments are carried out while the ends of the wires are being observed through a microscope to watch the effects of every operation. If the ends of the electrodes are shaped slightly convex there is no difficulty in clamping the wires between them and in fusing the wires together by the discharge. The energy in the discharge must be carefully adjusted so that the wires are not fused off. When the radio paper condenser, *T*, of 7 mfd. capacity was charged to about 35 volts, through the voltage-dividing rheostat, *S*, the wires were satisfactorily welded by the discharge.

Figure 8 shows the thermocouple circuits used for measuring the temperature difference between the rectum of the animal and any point in the body. *W* is the thermo-junction in the hypodermic needle. *A* and *C* are junctions insulated from each other and placed in a glass tube which is inserted in the rectum. Deflections of the galvanometer, *G*, indicate temperature differences between the needle in the body (junction *W*) and the rectum (junction *A*) while deflections of the galvanometer, *G'*, indicate temperature differences between the rectum (junction *C*) and the constant temperature bath, in which junction *D* is placed. Hence the temperature of the rectum can be accurately followed while temperatures of the organs are being compared with it. The galvanometer *G* (Leeds and Northrup, type HS), has a sensitivity such that a spot of light is moved 30 cm. on a ground glass scale at a distance of 1 meter when there is a temperature difference of 1°C. between the junctions *W* and *A*. The galvanometer, *G'*

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(Leeds and Northrup type R) with the adjustable series resistance at 34 ohms, has a sensitivity of 6 cm. for 1°C. temperature difference between the junctions *C* and *D*.

In order to increase the range of the temperature difference which can be measured by the galvanometer, *G*, the potentiometer shown at the left (fig. 8) is used. This consists of the low resistance, *R*, placed in series with the galvanometer, the high

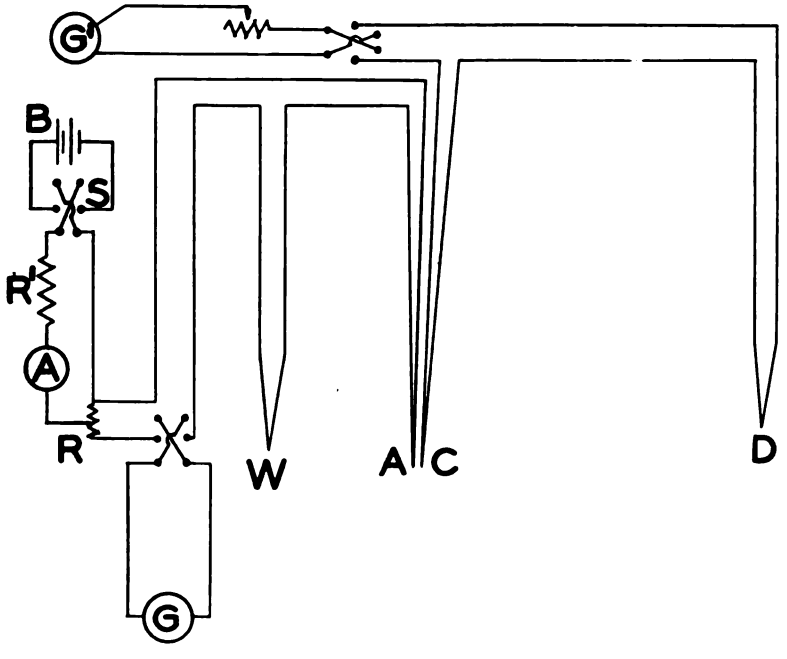

FIG. 8. CIRCUIT DIAGRAM

resistance, *R'*, 100,000 ohms, the microammeter, *A*, reversing switch, *S*, and storage battery, *B*. The resistance, *R*, is adjusted so that when the voltage of *B* is 4 volts and the switch *S* is closed, the galvanometer deflection equals that produced by a temperature difference of about 1°C. between *W* and *A*. As the resistance of the galvanometer circuit is large compared with *R*, the microammeter readings are approximately proportional to the galvanometer readings and hence are used to determine the suppression

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of the galvanometer deflections produced by the temperature differences between W and A. The deflections in either direction may be suppressed by means of the reversing switch, S.

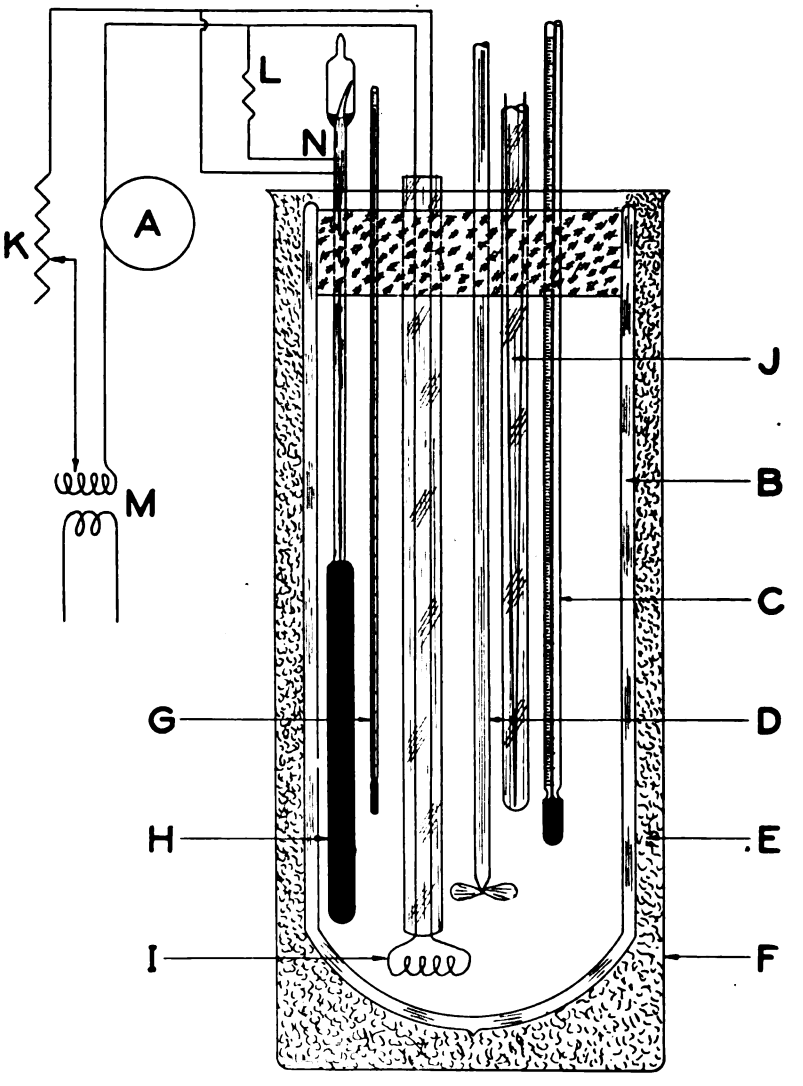

FIG. 9. DIAGRAM OF CONSTANT TEMPERATURE BATH

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The constant temperature bath (fig. 9), in which the junction, *J*, corresponding to *D*, figure 8, is immersed, consists of the silvered Dewar flask, *B*, supported in the beaker, *F*, and filled with a fluid lubricating oil. The oil is heated by the nichrome resistance coil, *I*, and stirred by the motor driven glass stirrer, *D*. The temperature of the bath is controlled at 38°C. to within less than 0.02°C. by the mercury regulator (Aminco type), *H*. When the resistance *L* is connected into the circuit by the closing of the

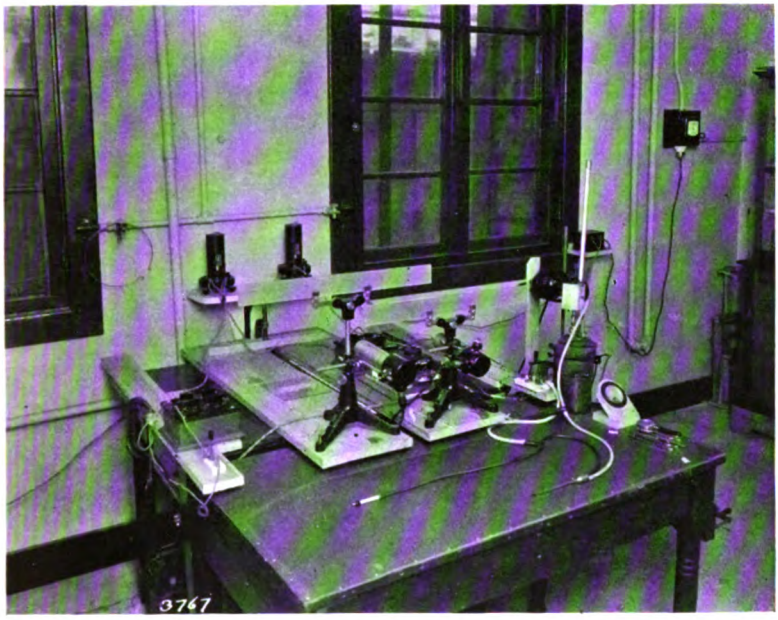

FIG. 10. PHOTOGRAPH OF APPARATUS

regulator contacts at *N*, the voltage across the heating coil, *I*, is decreased, thus decreasing the heating rate. If the rate of heating is adjusted by the resistance, *K*, and toy transformer, *M*, so that the temperature of the bath rises very slowly when *L* is not connected, the current which the regulator must interrupt can be reduced to a very small value. The temperature variations of the bath are shown on the Beckman thermometer, *C*, while the actual temperature is shown by the calibrated thermometer, *G*.

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The arrangement of the apparatus is shown in the photograph, figure 10. The hypodermic needle junction of the thermocouple is shown on the table in the foreground.

When temperature differences between two points in a tissue are measured, a thermocouple having both junctions mounted in needles is used. The thorough insulation of the junctions and wires insures freedom from chemical action on the wires and from change in the resistance of the measuring circuit due to the electrical conductivity of the body fluid.

The authors are grateful to Mr. H. A. Wagner, who made the work possible, to Dr. George Walker, whose work inspired the problem, and to Colonel R. B. Owens, D.S.O., for the facilities of the Maryland Academy of Sciences.

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THE DAMPING EFFECT ON A ROTATING PROJECTILE DUE TO THE PATH OF THE CENTER OF GRAVITY OF THE PROJECTILE*

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An explanation of the fact that the axis of a well-designed rotating projectile remains nearly in the line of the tangent to the trajectory during flight, in the opinion of the writer, has not heretofore been completely made. In his book "New Methods in Exterior Ballistics" Professor Moulton has given an excellent and direct treatment of the motion of a rotating projectile, taking into account the damping forces opposing the oscillations of projectiles. He has not, however, included in his discussion the effects of the forces that produce the spiral motion of the center of gravity of the projectile. These effects are included in this paper and it is shown that the complete explanation of the trailing of projectiles is due to the combined effects of the damping forces and those producing the spiral motion. In some cases the damping forces have the predominating effect and in other cases those that produce the spiral motion predominate.

The steady state solution, as developed by Professor Moulton, considering the curvature of the trajectory due to gravity, is not affected by this development and consequently explains successfully the drift of projectiles. The methods contained in this paper are an extension of those due to Professor Moulton and are not related to those developed by Fowler, Gallop, Lock, and Richmond.[1]

* Communicated by Major-General C. C. Williams, Chief of Ordnance, U. S. A., retired. Received for publication June 17, 1930.

[1] *Philosophical Transactions of the Royal Society of London*, 1920.

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The equations for the undamped motion of the projectile, as given on page 188, "New Methods in Exterior Ballistics," are:

$$\begin{aligned}
&\frac{d\omega_1}{dt} - (1-\lambda)\,\omega_2\,\omega_3 = \mu \sin\theta\cos\varphi \\
&\frac{d\omega_2}{dt} + (1-\lambda)\,\omega_1\,\omega_3 = -\mu \sin\theta\sin\varphi \\
&\frac{d\omega_3}{dt} = 0 \\
&\sin\theta\,\frac{d\psi}{dt} = \omega_1 \sin\varphi + \omega_2 \cos\varphi \\
&\frac{d\theta}{dt} = \omega_1 \cos\varphi - \omega_2 \sin\varphi \\
&\frac{d\varphi}{dt} = \omega_3 - \cos\theta\,\frac{d\psi}{dt}
\end{aligned} \tag{1}$$

where ω_1, ω_2, and ω_3 are angular velocities about the 1, 2, and 3 axes respectively, μ a coefficient which enters into the expression of the moment of exterior forces and λ, the ratio of the moment of inertia about the 03 axis to the moment of inertia about the axes perpendicular to 03. The subscripts and angles refer to the axes given in figure 1.

Two integrals exist, one of which expresses the energy relations and a second which is due to the fact that the moment of momentum about the η axis is constant. These are respectively

$$\sin^2\theta\left(\frac{d\psi}{dt}\right)^2 + \left(\frac{d\theta}{dt}\right)^2 + 2\,\mu\cos\theta = C_1 \tag{2}$$

$$\sin^2\theta\,\frac{d\psi}{dt} + \omega_3\,\lambda\cos\theta = C_2 \tag{3}$$

where C_1 and C_2 are constants. On making use of these integrals and letting $w = \cos\theta$, equations (1) reduce to an elliptic integral in w; viz.,

$$\frac{dw}{dt} = \sqrt{2\,\mu\,w^3 - (C_1 + \omega_3^2\,\lambda^2)\,w^2 + 2\,(C_2\,\omega_3\,\lambda - \mu)\,w + C_1 - C_2^2} \tag{4}$$

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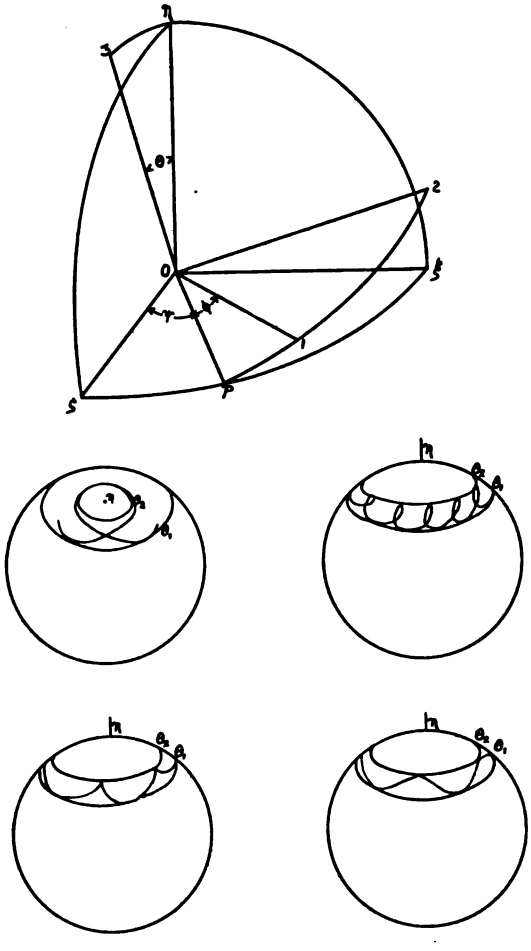
The analysis and solution of equation (4) indicates that the 03 axis oscillates between two limiting values of θ which we call θ_1 and θ_2. The corresponding cosines are w_1 and w_2. The resulting



FIGS. 1–5

types of oscillations given on pages 195 and 197, "New Methods in Exterior Ballistics," are shown in figures 2, 3, 4 and 5. The angle θ will be referred to hereafter as the angle of yaw and the plane

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η 03 as the plane of yaw. The angle of yaw will be defined as the angle between the axis of symmetry of the projectile and a line representing the instantaneous direction of motion of the center of gravity of the projectile.

In the problem to be considered now, C_1 and C_2 of equations (2) and (3) are not constant but variable quantities. It is proposed to study the variation of the limits w_1 and w_2 by considering the effects of the variations in C_1 and C_2. The following equations arise from this consideration:

$$\frac{dw_1}{dt} = \frac{\partial w_1}{\partial C_1} \cdot \frac{dC_1}{dt} + \frac{\partial w_1}{\partial C_2} \cdot \frac{dC_2}{dt}$$

$$\frac{dw_2}{dt} = \frac{\partial w_2}{\partial C_1} \cdot \frac{dC_1}{dt} + \frac{\partial w_2}{\partial C_2} \cdot \frac{dC_2}{dt} \qquad (5)$$

This procedure has been followed by Professor Moulton in considering the effects of the damping forces in retarding the oscillatory motion of the projectile in article 58, page 229, "New Methods in Exterior Ballistics." The following equations, which pertain to the oscillation of the projectile when the center of gravity moves in a straight line, are given on page 230.

$$\frac{d\omega_1}{dt} - (1 - \lambda)\,\omega_2\omega_3 = \mu \sin\theta \cos\varphi - \nu\,\omega_1$$

$$\frac{d\omega_2}{dt} + (1 - \lambda)\,\omega_1\omega_3 = -\mu \sin\theta \sin\varphi - \nu\,\omega_2$$

$$\frac{d\omega_3}{dt} = 0$$

$$\sin\theta \frac{d\psi}{dt} = \omega_1 \sin\varphi + \omega_2 \cos\varphi \qquad (6)$$

$$\frac{d\theta}{dt} = \omega_1 \cos\varphi - \omega_2 \sin\varphi$$

$$\frac{d\varphi}{dt} = \omega_3 - \cos\theta \frac{d\psi}{dt}$$

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Here ν is a coefficient due to a force directly opposing the oscillation of the projectile.

We next consider how these equations must be modified in order to take account of the effect of the spiral motion of the center of gravity. As a consequence of the oblique presentation of the projectile, the resultant force in the plane of yaw is not directly opposite the direction of motion of the center of gravity of the projectile. Assuming, however, that it does act through the longitudinal axis of the shell, and since it does not act through the center of gravity, this force may be resolved into a couple about an axis perpendicular to the plane of yaw and a force through the center of gravity. This couple and the component of this latter force along the tangent to the trajectory have been properly taken care of in Professor Moulton's treatment. He has not considered the effects of the component of this force perpendicular to the trajectory and in the plane of yaw. The component of this force along the tangent to the trajectory has been called, by Fowler and his associates, "the drag" and the component perpendicular to the tangent, "the cross wind force." The couple can be completely taken into consideration by expanding the first terms of the right-hand members of the first two of equations (6) as Fourier series in θ. The first term of such a series is at present written in equation (6). A comparison made by Mr. Hitchcock, at Aberdeen Proving Ground, of the method of determining stability factors for large angles of yaw by using Moulton's equation, in which only the first term of such a series is considered, and Fowler's method, in which the first two terms of such a series are used, indicated that in practice the results were the same. Hence, it is assumed that equations (6), in so far as the couple is concerned, are sufficiently accurate for present purposes.

The cross wind force causes the center of gravity of the projectile to depart from the rectilinear path used in Moulton's treatment of the effects of damping forces and results in the spiral motion referred to at the beginning of this paper. Equations (6) are based on the assumption of rectilinear motion in which

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the η axis represents the direction of motion of the center of gravity of the projectile. These equations have a somewhat different form when the projectile moves along a curved trajectory. The last three of equations (6) express the relation between the 1, 2, and 3 axes fixed in the projectile and the ξ, η and ζ axes referred to rectilinear motion along the trajectory and do not involve the exterior forces. Hence, it is possible to consider the change in the direction of motion of the center of gravity by rotat-

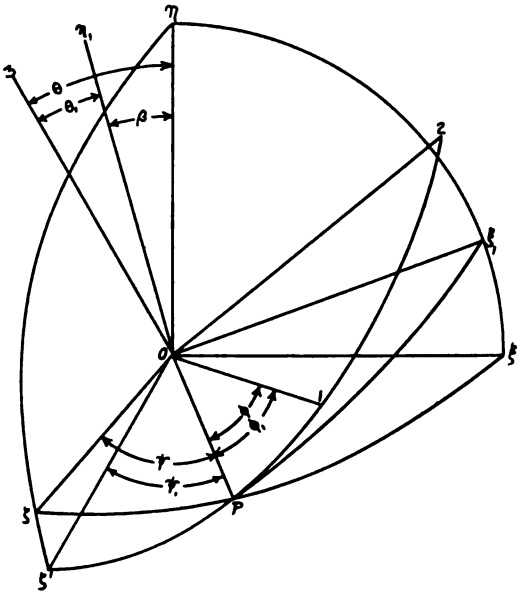

FIG. 6

ing the axes of reference so that the η axis is always in the direction of motion of the projectile. This changes the last three of equations (6) but leaves the right members of the first three unaltered.

Since the cross wind force acts always in the plane of yaw, a change in the direction of motion of the center of gravity of the projectile due to that force will take place in that plane. Letting

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η_1 represent such a position of the η-axis and θ_1, φ_1, and ψ_1 the new angular relations, it can be seen from figure 6 that

$$\begin{aligned} \varphi &= \varphi_1 \\ \theta &= \theta_1 + \beta \\ \psi &= \psi_1 \end{aligned} \tag{7}$$

Actually β is an infinitesmal while the time rate of change of β is a comparatively large quantity in magnitude approximately one-tenth to one-twentieth as large as the coefficient ν in equations (6). Therefore, $\sin\theta = \sin\theta_1$, $\cos\theta = \cos\theta_1$, for all practical purposes, and the terms in the transformed equations that are independent of $\frac{d\beta}{dt}$ have the same form as in equation (6). It follows from equation (7) that

$$\frac{d\theta}{dt} = \frac{d\theta_1}{dt} + \frac{d\beta}{dt} \tag{8}$$

Hence, the equations corresponding to (6) are found to be

$$\begin{aligned} \frac{d\omega_1}{dt} - (1-\lambda)\,\omega_2\omega_3 &= \mu \sin\theta_1 \cos\varphi_1 - \nu\,\omega_1 \\ \frac{d\omega_2}{dt} + (1-\lambda)\,\omega_1\omega_3 &= -\mu \sin\theta_1 \sin\varphi_1 - \nu\,\omega_2 \\ \frac{d\omega_3}{dt} &= 0 \end{aligned} \tag{9}$$

$$\begin{aligned} \sin\theta_1 \frac{d\psi_1}{dt} &= \omega_1 \sin\varphi_1 + \omega_2 \cos\varphi_1 \\ \frac{d\theta_1}{dt} &= \omega_1 \cos\varphi_1 - \omega_2 \sin\varphi_2 - \frac{d\beta}{dt} \\ \frac{d\varphi_1}{dt} &= \omega_3 - \cos\theta_1 \frac{d\psi_1}{dt} \end{aligned}$$

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From the first and second of equations (9), it follows that

$$\frac{d}{dt}(\omega_1^2 + \omega_2^2) = 2\mu \sin\theta_1 (\omega_1 \cos\varphi_1 - \omega_2 \sin\varphi_1) - 2\nu(\omega_1^2 + \omega_2^2)$$

On making use of the fifth of equations (9), it is found that

$$\frac{d}{dt}(\omega_1^2 + \omega_2^2) = 2\mu \sin\theta_1 \left(\frac{d\theta_1}{dt} + \frac{d\beta}{dt}\right) - 2\nu(\omega_1^2 + \omega_2^2) \tag{10}$$

It follows from the fourth and the fifth of equations (9) that

$$\omega_1^2 + \omega_2^2 = \sin^2\theta_1 \left(\frac{d\psi_1}{dt}\right)^2 + \left(\frac{d\theta_1}{dt} + \frac{d\beta}{dt}\right)^2 \tag{11}$$

On using this last equation and integrating equation (10), we find

$$\sin^2\theta_1 \left(\frac{d\psi_1}{dt}\right)^2 + \left(\frac{d\theta_1}{dt}\right)^2 + 2\mu\cos\theta_1 = -2\frac{d\theta_1}{dt}\frac{d\beta}{dt} - \left(\frac{d\beta}{dt}\right)^2 + 2\mu\int \sin\theta_1 \frac{d\beta}{dt}\,dt$$
$$- 2\nu\int (\omega_1^2 + \omega_2^2)\,dt + C_1^{(0)} \tag{12}$$

This equation expresses the energy relations existing during oscillation. The left-hand member of equation (12) has the same form as the left-hand member of equation (2). The terms involving β and ν may be regarded as producing slight modifications in the oscillations of undamped rectilinear motion. Hence, in the present problem

$$C_1 = -2\frac{d\theta_1}{dt}\frac{d\beta}{dt} - \left(\frac{d\beta}{dt}\right)^2 + \int 2\mu \sin\theta_1 \frac{d\beta}{dt}\,dt - \int 2\nu(\omega_1^2 + \omega_2^2)\,dt + C_1^{(0)} \tag{13}$$

It follows from equation (11) and (13) that

$$\frac{dC_1}{dt} = -2\frac{d\theta_1}{dt}\frac{d^2\beta}{dt^2} - 2\frac{d\beta}{dt}\left[\frac{d^2\theta_1}{dt^2} + \frac{d^2\beta}{dt^2} - \mu\sin\theta_1 + 2\nu\frac{d\theta_1}{dt} + \nu\frac{d\beta}{dt}\right]$$
$$- 2\nu\left[\sin^2\theta_1\left(\frac{d\psi}{dt}1\right)^2 + \left(\frac{d\theta_1}{dt}\right)^2\right] \tag{14}$$

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From the fifth of equations (9) eliminating ω_1 and ω_2, we have

$$\frac{d^2\theta_1}{dt^2} + \frac{d^2\beta}{dt^2} = -\sin\theta_1\left(\frac{d\psi_1}{dt}\right)\left(\omega_3 - \cos\theta_1\frac{d\psi_1}{dt}\right) + (1-\lambda)\,\omega_3\sin\theta_1\frac{d\psi_1}{dt} \tag{15}$$

$$+ \mu\sin\theta_1 - \nu\left(\frac{d\theta_1}{dt} + \frac{d\beta}{dt}\right)$$

On making use of equation (15), and dropping subscripts and denoting derivatives by the dots, equation (14) becomes

$$\frac{dC_1}{dt} = -2\nu\,[\sin^2\theta\,\dot{\psi}^2 + \dot{\theta}^2] - 2\dot{\beta}\,[\sin\theta\,\dot{\psi}\,(\cos\theta\,\dot{\psi} - \lambda\,\omega_3)] \tag{16}$$

$$- 2\dot{\theta}\,[\ddot{\beta} + \dot{\beta}\,\nu]$$

In the present problem the equation corresponding to (3) and expressing the moment of momentum relation is

$$\sin^2\theta_1\frac{d\psi_1}{dt} + \omega_3\lambda\cos\theta_1 = C_2 \tag{17}$$

It follows from equation (17) that

$$\frac{dC_2}{dt} = \frac{d}{dt}\left(\sin^2\theta_1\frac{d\psi_1}{dt} + \omega_3\lambda\cos\theta_1\right)$$

which becomes, after reducing by equations (9),

$$\frac{dC_2}{dt} = -\nu\sin^2\theta_1\frac{d\psi_1}{dt} - \sin\theta_1\frac{d\beta}{dt}\left(\cos\theta_1\frac{d\psi_1}{dt} - \omega_3\lambda\right)$$

On dropping subscripts and denoting derivatives by the dot, it is found that

$$\frac{dC_2}{dt} = -\nu\sin^2\theta\,\dot{\psi} - \sin\theta\,\dot{\beta}\,(\cos\theta\,\dot{\psi} - \omega_3\lambda) \tag{18}$$

Referring to page 231, "New Methods in Exterior Ballistics," it is seen that the first terms in the right-hand members of equations (16) and (18) are the same as those treated by Professor Moulton in considering the damping effect of the force opposing

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oscillation. The effects of these terms on the limiting values of yaw are given in equation (112), page 233. The derivatives of C_1, and C_2 in so far as they have not been treated, are therefore

$$\frac{dC_1}{dt} = -2\dot{\beta}\,[\sin\theta\,\dot{\psi}\,(\cos\theta\,\dot{\psi} - \lambda\,\omega_3)] - 2\,\dot{\theta}\,(\ddot{\beta} + \dot{\beta}\,\nu)$$

$$\frac{dC_2}{dt} = -\dot{\beta}\sin\theta\,(\cos\theta\,\dot{\psi} - \lambda\,\omega_3) \tag{19}$$

In the present discussion ω_3 has the constant value a_3. Letting $w = \cos\theta$, equations (19) become

$$\frac{dC_1}{dt} = -2\,\dot{\beta}\,\sqrt{1 - w^2}\,\dot{\psi}\,(w\,\dot{\psi} - a_3\,\lambda) - 2\,\frac{\dot{w}}{\sqrt{1 - w^2}}\,(\ddot{\beta} + \dot{\beta}\,\nu)$$

$$\frac{dC_2}{dt} = -\dot{\beta}\,\sqrt{1 - w^2}\,(w\,\dot{\psi} - a_3\,\lambda) \tag{20}$$

The partial derivatives of w_1 with respect to C_1 and C_2 as given on page 232, "New Methods in Exterior Ballistics," are

$$\frac{\partial w_1}{\partial C_1} = \frac{-(1 - w_1^2)}{2\,\mu\,(w_2 - w_1)\,(w_3 - w_1)}$$

$$\frac{\partial w_1}{\partial C_2} = \frac{C_2 - a_3\,\lambda\,w_1}{\mu\,(w_2 - w_1)\,(w_3 - w_1)} \tag{21}$$

Since the departures from undamped values are slight in the time interval considered, all quantities in the right-hand members of equations (20) and (21) will be considered as having their undamped values. Hence, from equations (40) and (42), pages 193 and 194, "New Methods in Exterior Ballistics," it follows that

$$\dot{\psi} = \frac{C_2 - a_3\,\lambda\,w}{1 - w^2} \tag{22}$$

$$C_2 = a_3\,\lambda\left[\frac{1 + w_1\,w_2}{w_1 + w_2} \pm \frac{\sqrt{(1 - w_1^2)\,(1 - w_2^2)\,(1 - S)}}{w_1 + w_2}\right] \tag{23}$$

$$S = \frac{2\,(w_1 + w_2)\,\mu}{a_3^2\,\lambda^2} \tag{24}$$

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Then

$$w\,\dot{\psi} - a_3\lambda = \frac{C_2\,w - a_3\lambda}{1 - w^2} \tag{25}$$

On using equations (20), (21), (22), and (25), the first of the equations (5) becomes

$$\left(\frac{dw_1}{dt}\right)_\beta = \frac{\dot{\beta}\,(C_2\,w - a_3\lambda)\,[C_2\,(w + w_1) - a_3\lambda\,(1 + w_1\,w)]\,(w - w_1)}{\mu\,(w_2 - w_1)\,(w_3 - w_1)\,(1 - w^2)^{3/2}}$$

$$- \frac{\dot{w}\,(\ddot{\beta} + \dot{\beta}\,\nu)\,(1 - w_1^2)}{\mu\,(w_2 - w_1)\,(w_3 - w_1)\,\sqrt{1 - w^2}} \tag{26}$$

The time rate of change of w_2 can be obtained from (26) by permuting w_1 and w_2. It follows that

$$\left(\frac{dw_2}{dt}\right)_\beta = \frac{\dot{\beta}\,(C_2\,w - a_3\lambda)\,[C_2\,(w + w_2) - a_3\lambda\,(1 + w_2\,w)]\,(w_2 - w)}{\mu\,(w_2 - w_1)\,(w_3 - w_2)\,(1 - w^2)^{3/2}}$$

$$+ \frac{w\,(\ddot{\beta} + \dot{\beta}\,\nu)\,(1 - w_2^2)}{\mu\,(w_2 - w_1)\,(w_3 - w_2)\,\sqrt{1 - w^2}} \tag{27}$$

It follows from equation (23) that

$$C_2\,(w+w_1) - a_3\lambda\,(1+ww_1) = \frac{a_3\lambda\,(w-w_2)\,(1-w_1^2) \pm a_3\lambda\,(w+w_1)\,\sqrt{(1-w_1^2)\,(1-w_2^2)\,(1-S)}}{w_1 + w_2} \tag{28}$$

$$C_2\,(w+w_2) - a_3\lambda\,(1+ww_2) = \frac{a_3\lambda\,(w-w_1)\,(1-w_2^2) \pm a_3\lambda\,(w+w_2)\,\sqrt{(1-w_1^2)\,(1-w_2^2)\,(1-S)}}{w_1 + w_2}$$

$$C_2\,w - a_3\lambda = \frac{a_3\lambda\,[w(1+w_1w_2) - (w_1+w_2)] \pm a_3\lambda\,w\,\sqrt{(1-w_1^2)\,(1-w_2^2)\,(1-S)}}{w_1 + w_2} \tag{29}$$

Without further reduction at this stage certain facts are evident from a consideration of equations (26), (27), (28), and (29).

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When $w = w_2$, it is found that

$$\left(\frac{dw_1}{dt}\right)_\beta = \frac{\dot{\beta}\, a_3^2 \lambda^2 \sqrt{1-w_1^2}\sqrt{1-S}\left[\mp w_1 + w_2\sqrt{\frac{1-w_1^2}{1-w_2^2}}\sqrt{1-S}\right]}{\mu\,(w_1+w_2)\,(w_3-w_1)} \tag{30}$$

$$\left(\frac{dw_2}{dt}\right)_\beta = 0$$

When $w = w_1$

$$\left(\frac{dw_1}{dt}\right)_\beta = 0$$

$$\left(\frac{dw_2}{dt}\right)_\beta = \frac{\dot{\beta}\, a_3^2 \lambda^2 \sqrt{1-w_2^2}\sqrt{1-S}\left[\mp w_2 + w_1\sqrt{\frac{1-w_2^2}{1-w_1^2}}\sqrt{1-S}\right]}{\mu\,(w_1+w_2)\,(w_3-w_2)} \tag{31}$$

The upper sign in the bracket belongs to the type of motion illustrated in figure 2 and the lower sign to the type illustrated in figures 3, 4, and 5.

All the terms in these equations are positive except the terms in brackets. Consider first equation (30). The limit w_1 will increase or decrease, depending upon whether the term in brackets is positive or negative. That is, the maximun limit of yaw θ_1 will approach the tangent to the trajectory if the term is positive and will become larger if the term is negative. When the lower sign is used, the term is positive. When the upper sign is used, the term is positive unless S is a much larger quantity than is ever found in practice for a well-designed projectile. For example, for $\theta_1 = 5°$ and $\theta_2 = 2°$, S must be greater than 0.8. Therefore, the effect of the curved path of the center of gravity on the maximum limit of yaw due to the force exerted when the axis of the shell is passing through the minimum limit of yaw is to cause in general a decrease in the larger limit for all types of motion.

It can be seen from equation (31) that when the lower sign is used the smaller limit of yaw will decrease because the term in brackets is positive. When the upper sign is used, the term in

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brackets is negative. Hence, the effect of the curved path of the center of gravity on the smaller limit of yaw, due to the force exerted when the axis of the shell is passing through the larger limit of yaw, is to cause an increase in the smaller limit of yaw when the motion is of the type illustrated in figure 2, and a decrease when the motion is of the types illustrated in figures 3, 4, and 5.

From Professor Moulton's treatment, the effect of the force opposing oscillation on the larger limit of yaw due to the force exerted when the axis of the shell is passing through the smaller limit of yaw, is to cause a decrease in the larger limit of yaw for motion of the type illustrated in figure 2, and to cause the

TABLE 1

COMBINED EFFECT OF DAMPING FORCES

TYPE OF MOTION	WHEN $\theta = \theta_1$		WHEN $\theta = \theta_2$	
	Effect on θ_2 of		Effect of θ_1 of	
	Curvature	Force opposing oscillation	Curvature	Force opposing oscillation
Figure 2	Increase	Decrease	Decrease	Decrease
Figure 3	Decrease	Increase	Decrease	Decrease
Figure 4	Decrease	Increase	Decrease	Stationary
Figure 5	Decrease	Increase	Decrease	Increase

larger limit to increase, remain stationary, or decrease according as the motion is of the type illustrated in figures 5, 4, or 3, respectively. The effect of the force opposing oscillation on the smaller limit of yaw when the axis of the shell is passing through the larger limit of yaw is to cause a decrease in the smaller limit for motion of type, figure 2, and an increase for motion of types, figures 3, 4, and 5. Table 1 will give a better idea of the combined effect of these two damping forces. It can be seen from the treatment thus far, that, for the special case when $w = w_1$ and $w = w_2$, the two damping forces either combine to decrease the yaw or have opposing effects.

The treatment of the general case has involved a great deal of

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laborious computation. $\dot{\beta}$ and ν are both small quantities. $\ddot{\beta}$ is also small compared with $\dot{\beta}$ or ν. Hence the second terms in the right-hand members of equations (26) and (27) are second order terms and may be neglected without appreciable error. On making use of (28) and (29) equations (26) and (27) become

$$\left(\frac{dw_1}{dt}\right)_\beta = \frac{\dot{\beta}\, a_3^2 \lambda^2 \sqrt{1-w_1^2}\left[\left\{w(1+w_1w_2) - (w_1+w_2) \pm w\sqrt{(1-w_1^2)\,(1-w_2^2)\,(1-S)}\right\}\right.}{\left.\left\{(w-w_2)\sqrt{1-w_1^2} \pm (w+w_1)\sqrt{(1-w_2^2)\,(1-S)}\right\}\right](w-w_1)}{\mu\,(w_2-w_1)\,(w_3-w_1)\,(w_1+w_2)^2\,(1-w^2)^{3/2}}$$

$$\left(\frac{dw_2}{dt}\right)_\beta = \frac{\dot{\beta}\, a_3^2 \lambda^2 \sqrt{1-w_2^2}\left[\left\{w(1+w_1w_2) - (w_1+w_2) \pm w\sqrt{(1-w_1^2)\,(1-w_2^2\,(1-S)}\right\}\right.}{\left.\left\{(w-w_1)\sqrt{1-w_2^2} \pm (w+w_2)\sqrt{(1-w_1^2)\,(1-S)}\right\}\right](w_2-w)}{\mu\,(w_2-w_1)\,(w_3-w_2)\,(w_1+w_2)^2\,(1-w^2)^{3/2}} \tag{32}$$

All terms in the above equations are positive, except those in brackets. Hence, the limits of yaw θ_1 and θ_2 will decrease or increase according as this expression is positive or negative. Rather than discuss the above equations in general, the writer has chosen a numerical illustration, using all terms containing the variable w in the above equations. This brings out, in addition to the sign, the relative magnitude of the terms involved. Rewriting equation (32) for convenience of notation thus:

$$\left(\frac{dw_1}{dt}\right)_\beta = -\frac{\dot{\beta}\, a_3^2\, \lambda^2 \sqrt{1-w_1^2}\, W_1^{\pm}}{\mu\,(w_2-w_1)\,(w_3-w_1)\,(w_1+w_2)^2}$$

$$\left(\frac{dw_2}{dt}\right)_\beta = -\frac{\dot{\beta}\, a_3^2\, \lambda^2 \sqrt{1-w_2^2}\, W_2^{\pm}}{\mu\,(w_2-w_1)\,(w_3-w_2)\,(w_1+w_2)^2} \tag{33}$$

where W_1^+ and W_2^+ refer to motion of the type illustrated in figure 2 and W_1^- and W_2^- refer to motion of type illustrated in figures 3, 4, and 5. Assuming values of S and θ which may be expected in the average well designed projectiles, the value of the terms $W_1^{\pm}$ and $W_2^{\pm}$ have been calculated for $S = 0.4, 0.5, 0.6$, and 0.7, for $\theta_1 = 5°$, for $\theta_2 = 2°$, and for various values of θ between $2°$ and $5°$. Graphs showing the relative magnitude of these terms are given in figures 7, 8, 9, 10. The numerical values of these terms for $S = 0.5$ are given in table 2. It is noted that W^- and

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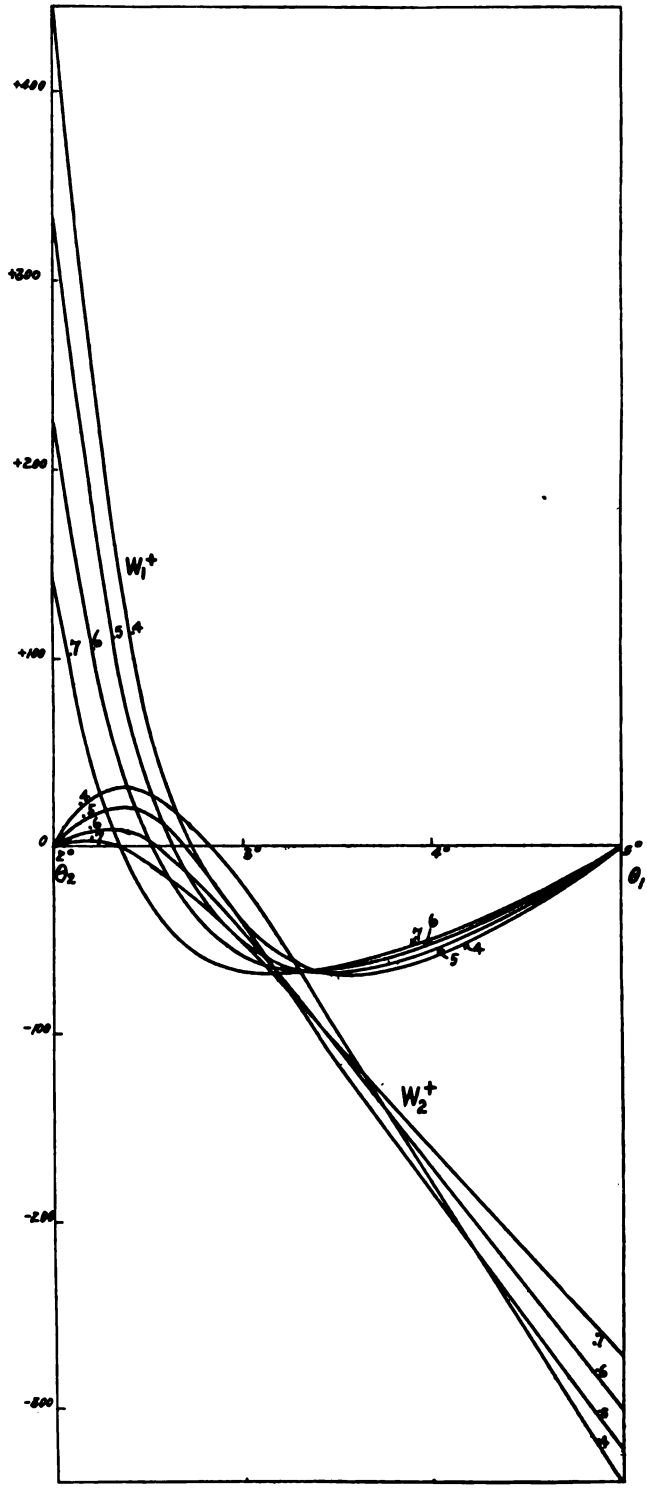

FIG. 7. RELATIVE MAGNITUDE FOR VARIOUS VALUES OF S OF TERMS CONTAINING THE VARIABLE w IN THE EXPRESSION FOR $\left(\frac{dw_1}{dt}\right)_\beta$ AND $\left(\frac{dw_2}{dt}\right)_\beta$ WHEN THE UPPER SIGN IS USED IN THE BRACKET IN EQUATION (32)

Note: Motion is of type illustrated in figure 2. Positive values indicate decreasing values of θ_1 and θ_2. Negative values indicate increasing values of θ_1 and θ_2.

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W_2^- in this illustration refer to motion of the type figure 3 only. Reference to the criterion for differentiating between the types 3, 4, and 5, given on page 197, "New Methods in Exterior Ballistics," indicates that, unless θ_1 and θ_2 are much more nearly equal

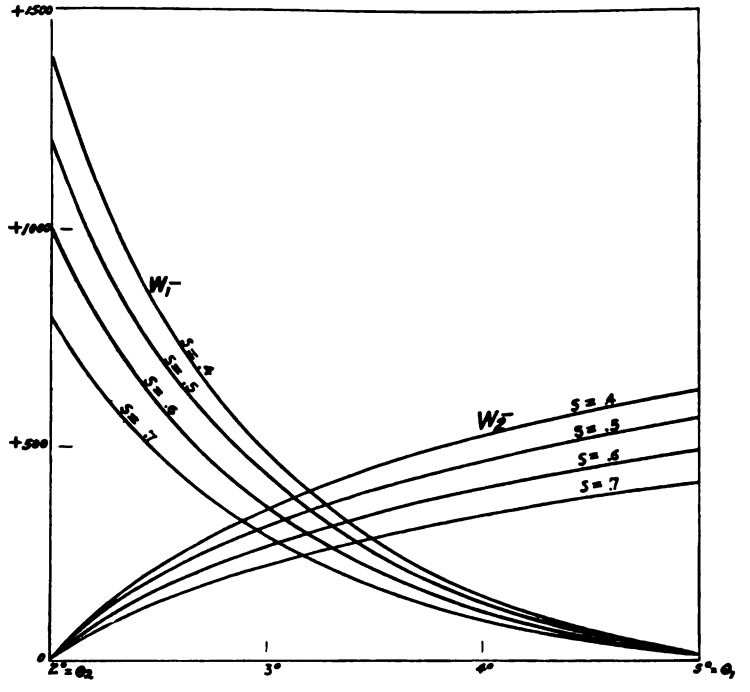

FIG. 8. RELATIVE MAGNITUDE FOR VARIOUS VALUES OF S OF TERMS CONTAINING THE VARIABLE w IN THE EXPRESSIONS FOR $\left(\frac{dw_1}{dt}\right)_\beta$ AND $\left(\frac{dw_2}{dt}\right)_\beta$ WHEN THE LOWER SIGN IS USED IN BRACKET IN EQUATION (32)

Note: Motion is of type illustrated in figure 3. The positive value of these terms indicate that both θ_1 and θ_2 decrease for this type of motion.

than the limits used, or $S > 0.84$, motion of the types 4 and 5 do not occur.

Referring now to figure 7, positive values of W_1^+ and W_2^+ indicate that θ_1 and θ_2 will decrease while negative values indicate an increase in the limits of yaw. The magnitude of these values

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indicates the relative speed with which the damping occurs. It can be seen, therefore, that for motion of the type 2 as the axis of the shell passes from the smaller to the larger limit of yaw, θ_2

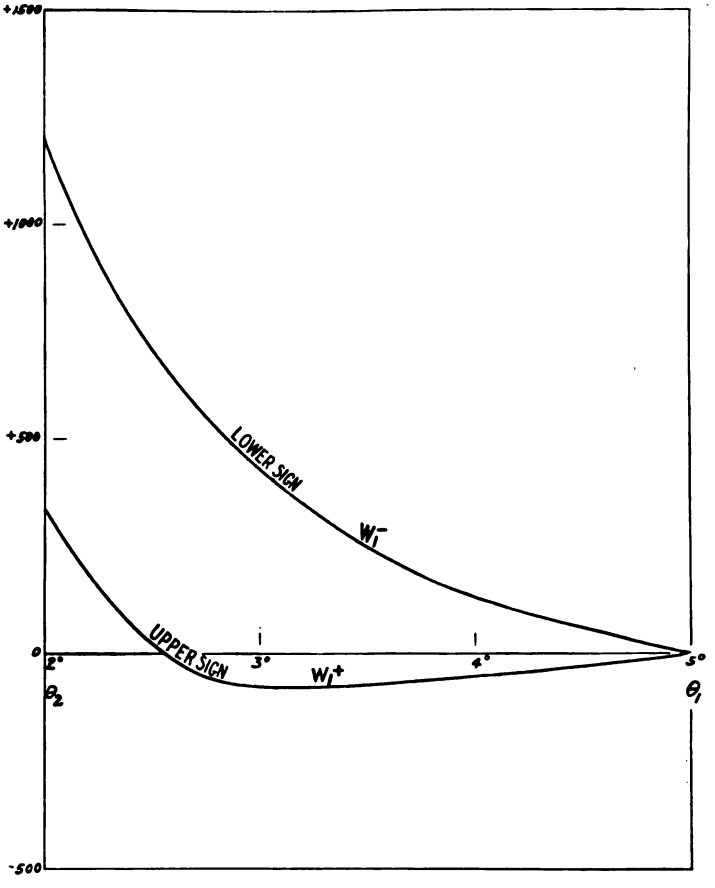

FIG. 9. RELATIVE MAGNITUDE FOR $S = 0.5$ OF TERMS CONTAINING THE VARIABLE w IN THE EXPRESSIONS FOR $\left(\frac{dw_1}{dt}\right)_\beta$

decreases slowly while the axis is near θ_2 and increases rapidly as the axis approaches the other limit. θ_1 decreases rapidly while the axis is near θ_2, and increases less rapidly as the axis approaches θ_1. It may be said, however, that the effect of the curvature of

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the path of the center of gravity for motion of type 2 is to cause both of the limits of yaw to increase, θ_2 much more than θ_1.

Referring to figure 8, it can be seen that, for motion of the type 3 the effect of the curvature of the path of the center of gravity is to cause both limits to decrease. It can be seen further, from

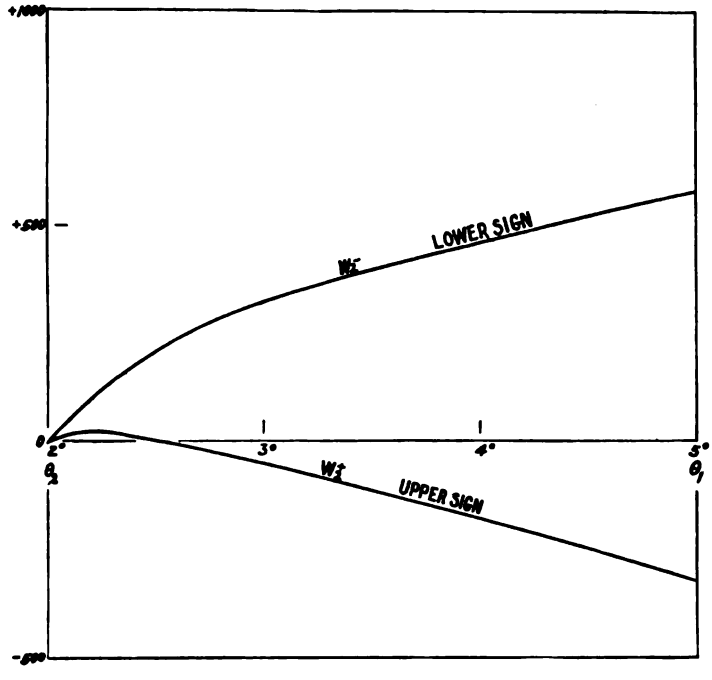

FIG. 10. RELATIVE MAGNITUDE FOR $S = 0.5$ OF TERMS CONTAINING THE VARIABLE w IN THE EXPRESSION FOR $\left(\frac{dw_2}{dt}\right)_\beta$

these two figures, that the smaller the stability factory, the more effective will be the damping.

Figures 9 and 10 illustrate the relative magnitude of the damping effects due to curvature of the path on the limits θ_1 and θ_2 respectively. It can be seen that the damping is much more rapid for the type of motion, figure 3, than for motion of the type 2.

Equations (112), page 223, "New Methods in Exterior Ballis-

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tics," which treat of the damping effect due to the force opposing oscillation, are:

$$\left(\frac{dw_1}{dt}\right)_\nu = \frac{\nu\,(a_2^2\lambda^2)\sqrt{1-w_1^2}\sqrt{1-S}\left[\sqrt{1-w_1^2}\sqrt{1-S} \pm \sqrt{1-w_2^2}\right](w-w_1)}{\mu\,(w_1+w_2)\,(w_2-w_1)\,(w_3-w_1)}$$

$$\left(\frac{dw_2}{dt}\right)_\nu = \frac{\nu\,a_3^2\lambda^2\sqrt{1-w_2^2}\sqrt{1-S}\left[\sqrt{1-w_2^2}\sqrt{1-S} \pm \sqrt{1-w_1^2}\right](w_2-w)}{\mu\,(w_1+w_2)\,(w_2-w_1)\,(w_3-w_2)} \qquad (34)$$

the upper sign in the bracket belonging to the type of oscillation illustrated in figure 2, and the lower sign to the types illustrated in figures 3, 4, and 5. When the upper sign is used in the bracket, every factor in the right-hand members of equation (34) is positive

TABLE 2

NUMERICAL VALUES

θ	W_1^+	W_2^+	W_1^-	W_2^-
5°	0	−0.00324	0	+0.00579
4° 18′	−0.00040	−0.00223	+0.00091	+0.00501
3° 27′	−0.00070	−0.00106	+0.00261	+0.00390
2° 18′	+0.00121	+0.00021	+0.00860	+0.00143
2°	+0.00331	0	+0.01200	0.0

except when $w - w_1 = 0$ or $w - w_2 = 0$. Therefore, in the type of oscillation illustrated in figure 2, the damping force opposing oscillation decreases both θ_1 and θ_2. When the lower sign is used in the brackets, the bracket in the second equation is negative because $1-S < 1$ and $w_1 < w_2$. The bracket in the first equation is negative, zero, or positive according as

$$\sqrt{1-w_2^2} \gtreqless \sqrt{1-w_1^2}\sqrt{1-S} \qquad (35)$$

Since θ_1 is usually several times θ_2, the third of these possibilities will hold unless S is near unity. These three cases correspond respectively to the types of oscillation illustrated in figures 5, 4, and 3. In the numerical illustration which we have used, only motion of the type 3 occurs.

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A comparison based on this numerical illustration shows the combined effects of the two damping forces to be as shown in table 3.

As a concluding argument, a comparison of equations (32) and (34) will now be made by dividing equations (34) by the corresponding equations of (32)

$$\frac{\left(\frac{dw_1}{dt}\right)_\nu}{\left(\frac{dw_1}{dt}\right)_\beta} = \frac{\nu\sqrt{1-S}\,(w_1+w_2)\left[\sqrt{1-w_1^2}\sqrt{1-S} \pm \sqrt{1-w_2^2}\right](1-w^2)^{3/2}}{\dot{\beta}\left\{w(1+w_1w_2)-(w_1+w_2) \pm w\sqrt{(1-w_1^2)(1-w_2^2)(1-S)}\right\}\left\{(w-w_2)\sqrt{1-w_1^2} \pm (w+w_1)\sqrt{(1-w_2^2)(1-S)}\right\}} \tag{36}$$

$$\frac{\left(\frac{dw_2}{dt}\right)_\nu}{\left(\frac{dw_2}{dt}\right)_\beta} = \frac{\nu\sqrt{1-S}\,(w_1+w_2)\left[\sqrt{1-w_2^2}\sqrt{1-S} \pm \sqrt{1-w_1^2}\right](1-w^2)^{3/2}}{\dot{\beta}\left\{w(1+w_1w_2)-(w_1+w_2) \pm w\sqrt{(1-w_1^2)(1-w_2^2)(1-S)}\right\}\left\{(w-w_1)\sqrt{1-w_2^2} \pm (w+w_2)\sqrt{(1-w_1^2)(1-S)}\right\}}$$

Writing this equation for convenience of notation in the following form, the coefficient of $\frac{\nu}{\dot{\beta}}$ has been calculated for all values used in the above illustration.

$$\frac{\left(\frac{dw_1}{dt}\right)_\nu}{\left(\frac{dw_1}{dt}\right)_\beta} = X_1^{\pm}\frac{\nu}{\dot{\beta}}$$

$$\frac{\left(\frac{dw_2}{dt}\right)_\nu}{\left(\frac{dw_2}{dt}\right)_\beta} = X_2^{\pm}\frac{\nu}{\dot{\beta}} \tag{37}$$

In table 4 X_1^+ and X_2^+ refer to motion of type 2, while X_1^- and X_2^- refer to motion of type 3. The plus sign indicates that the damping effects are in the same direction, while the minus sign indicates opposing effects.

A comparison of this table with table 3 or with figures 7 and 8 indicates that for motion of type 2, since $\dot{\beta}$ is approximately

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$\frac{\nu}{15}$, that the force opposing oscillation has in general the predominating effect. Hence, both θ_1 and θ_2 will decrease. For motion of type 3 the curvature of the path has the predominating effect. Hence, both θ_1 and θ_2 decrease, but θ_1 much more rapidly than θ_2. That is, while θ_1 and θ_2 both decrease, they are approaching equality. It can be seen from equation (35) that, when these limits are sufficiently near each other it is possible for motion of type 3 to change into motion of type 4 and 5. Referring, now, to equation (32), the first term $(w - w_2)\sqrt{1 - w_1^2}$ in the second brace of the brackets is always so much smaller than the second term that it will never affect the sign of the second brace unless $w_2 = 1$ and, therefore, may be

TABLE 3

COMPARISON OF COMBINED EFFECTS OF DAMPING FORCES

TYPE OF MOTION	EFFECT ON θ_1 OF		EFFECT ON θ_2 OF	
	Curvature of path	Force opposing oscillation	Curvature of path	Force opposing oscillation
Figure 2	Increase	Decrease	Increase	Decrease
Figure 3	Decrease	Decrease	Decrease	Increase

neglected. Further, the term $1 + w_1 w_2 \doteq w_1 + w_2$ in the first brace. Therefore, equation (32) may be written without introducing any error in sign in the following form:

$$\left(\frac{dw_1}{dt}\right)_\beta = \frac{\dot{\beta}\, a_3^2 \lambda^2 (w_1 + w)\sqrt{(1 - w_1^2)(1 - w_2^2)(1 - S)}}{\mu (w_2 - w_1)(w_3 - w_1)(w_1 + w_2)^2 (1 - w^2)^{3/2}} \cdot \frac{\left[\mp (w_1 + w_2)(1 - w) + w\sqrt{(1 - w_1^2)(1 - w_2^2)(1 - S)}\right](w - w_1)}{}$$

$$\left(\frac{dw_2}{dt}\right)_\beta = \frac{\dot{\beta}\, a_3^2 \lambda^2 (w_2 + w)\sqrt{(1 - w_1^2)(1 - w_2^2)(1 - S)}}{\mu (w_2 - w_1)(w_3 - w_2)(w_1 + w_2)^2 (1 - w^2)^{3/2}} \cdot \frac{\left[\mp (w_1 + w_2)(1 - w) + w\sqrt{(1 - w_1^2)(1 - w_2^2)(1 - S)}\right](w_2 - w)}{}$$

When the lower sign is used in the bracket, that is, when the motion is of the type 3, 4, or 5,

$$\left(\frac{dw_1}{dt}\right)_\beta \text{ and } \left(\frac{dw_2}{dt}\right)_\beta$$

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are both positive. Therefore, the effect of curvature of the path is to cause both θ_1 and θ_2 to decrease regardless of whether the motion is of the type 3, 4, or 5. It can be seen from equation (34) that for motion of type 4 or 5, the effect of force opposing oscillation is to increase θ_2 and to cause θ_1 to remain stationary or increase. A numerical calculation for values involved will show that the curvature is the predominating effect as in the case of motion of type 3. Again θ_1 decreases more rapidly than θ_2 and the limits approach equality.

Take the limiting case where $w_0 = w_1 = w_2$. Equation (36) becomes

$$\frac{\left(\frac{dw_0}{dt}\right)_\nu}{\left(\frac{dw_0}{dt}\right)_\beta} = \frac{\nu\sqrt{1-w_0^2}\left[\sqrt{1-S}\pm 1\right]}{\dot{\beta}\, w_0\left[\sqrt{1-S}\mp 1\right]} \tag{38}$$

This equation holds approximately for values of θ_1 and θ_2 near each other, and indicates the predominating effect of curvatures when the motion is of the type 3, 4, or 5, and the predominating effect of the force opposing oscillation for motion of type 2.

The influence of increasing values of S may be seen by inspecting table 2. The coefficients X_1^+ and X_2^+, which belong to the problem for motion of type 2, decrease with increasing values of S, thus allowing the curvature to have greater effect on the motion. This leads to a slower rate of decrease of the limits θ_1 and θ_2, and makes for more unstable motion. The coefficients X_1^- decreases while S increases and X^- increases while S increases, thus allowing the curvature to have a greater effect on the limit θ_1 and the force opposing oscillation a greater effect on the limit θ_2. Hence, if S is sufficiently large and the limits of yaw sufficiently far apart, θ_2 may actually increase, while θ_1 decreases for motion of type 3. However, as the limits get sufficiently near each other, it may be seen from equation (38) that the curvature has the predominating effect and both limits θ_1 and θ_2 decrease.

It follows from the discussion above, that the limits of yaw in the well-designed projectile decrease for all types of motion, and, if the two forces, which have been treated in this paper, were the

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only forces affecting this motion, that the oscillations of the projectile would be damped out and that the axes of the projectile would eventually coincide with the tangent to a rectilinear trajectory. However, the curvature of the trajectory due to gravity

TABLE 4

θ	x_1^+	x_2^+	x_1^-	x_2^-
		$S = 0.4$		
5°	−0.3509	−0.1651	+0.0663	−0.0459
4° 18′	−0.3578	−0.1692	+0.0442	−0.0365
3° 27′	−0.4417	−0.2266	+0.0352	−0.0252
2° 18′	+0.2371	+0.1151	+0.0136	−0.0119
2°	+0.1036	+0.0490	+0.0099	−0.0082
		$S = 0.5$		
5°	−0.3368	−0.1557	+0.0579	−0.0489
4° 18′	−0.3382	−0.1513	+0.0515	−0.0388
3° 27′	−0.3868	−0.1786	+0.0290	−0.0271
2° 18′	+0.3353	+0.1564	+0.0131	−0.0123
2°	+0.1264	+0.0585	+0.0097	−0.0090
		$S = 0.6$		
5°	−0.3030	−0.1460	+0.0401	−0.0520
4° 18′	−0.2962	−0.1430	+0.0323	−0.0418
3° 27′	−0.3338	−0.1615	+0.0228	−0.0294
2° 18′	+0.5558	+0.2963	+0.0106	−0.0136
2°	+0.1875	+0.0758	+0.0078	−0.0101
		$S = 0.7$		
5°	−0.2664	−0.1359	+0.0262	−0.0558
4° 18′	−0.2543	−0.1300	+0.0212	−0.0452
3° 27′	−0.2660	−0.1363	+0.0152	−0.0323
2° 18′	+3.4330	+0.1787	+0.0072	−0.0154
2°	+0.2164	+0.1161	+0.0054	−0.0113

gives rise to an approximate steady state solution in which the axis of the projectile lies a little to the right of and slightly below the tangent to the trajectory for guns with right-handed rifling. This fact explains drift. A discussion of this effect is given by Professor Moulton in articles 59 to 62 in his treatment of the motion

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of a rotating projectile. While it is intuitively evident that the periodic terms which arise in Professor Moulton's discussion may be able to change the motion from motion of type 2 to motions of type 3, 4, or 5 or the reverse, the writer has never been able to show this quantitatively. Experimental evidence up to the present has only shown that the change takes place from motion of type 2 to motion of type 3, 4, or 5. The necessity for the reverse effect, which Moulton uses in his explanation of damping, has been obviated by the discussion in this paper.

The writer desires to thank Professor Moulton for his cooperation and guidance in the writing of this paper, and Mr. Kent who, in a review of "New Methods in Exterior Ballistics," pointed out the fact that Moulton had not treated the "cross wind force."

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TORQUE METER FOR MEASUREMENT OF POWER OUTPUT OF AIRCRAFT ENGINES IN FLIGHT*[1, 2]

D. ADAM DICKEY, B.E.E.

Chief of the Propeller Unit, Materiel Division, Wright Field, Dayton, Ohio

There has always been a point in question as to where to place the blame for failure of an aircraft to perform in accordance with expectations. The uncertainty is more pronounced in the case of craft operating at high altitudes, and a three-cornered argument almost invariably ensues as the power plant engineer, the airplane engineer, and the propeller engineer each attempts to defend his respective equipment from blame.

In the hope of clarifying the situation, various attempts have been made to evolve a light, dependable, and easily applied

* Communicated by Major-General James E. Fechet, Chief of the Air Corps, U. S. A. Received for publication June 13, 1930.

[1] The torque meter described in this paper was originally suggested by Mr. M. A. Smith, formerly chief of the propeller unit, who with Mr. Norman N. Tilley of the Power Plant Branch perfected plans for its design and development in the summer of 1928. Mr. Tilley resigned from the Materiel Division before any steps toward the actual development had been taken and the final plans, the design, construction, installation, and initial test were continued under the supervision of Mr. Smith, who also resigned from the Division in the fall of 1929, soon after the flight test program had been started.

The torque meter units and hydrostatic system are the design of, and were built by Mr. A. H. Emery of Stamford, Connecticut. The Allison Engineering Company, Indianapolis, Indiana, manufactured the planetary gear unit as well as the engine.

[2] AIR CORPS

MATERIEL DIVISION

OFFICE OF THE CHIEF OF DIVISION

Wright Field, Dayton, Ohio.
June 5, 1930.

MY DEAR GENERAL:

Referring to your letter of May 22, 1930, concerning an article on propellers for the Maryland Academy of Sciences, the inclosed report on the "Torque Meter" has been compiled by Mr. D. A. Dickey, Chief of the Propeller Unit. It is in-

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torque meter by means of which the actual power output of the engine may be determined at any time during flight. No universally satisfactory torque meter of the type desired has as yet come to the attention of the Materiel Division, but the one described in this paper has proved satisfactory for use with the particular type of engine to which it has been applied. The type of gear reduction employed in the epicyclic-geared Liberty engines lends itself admirably to the measurement of torque forces.

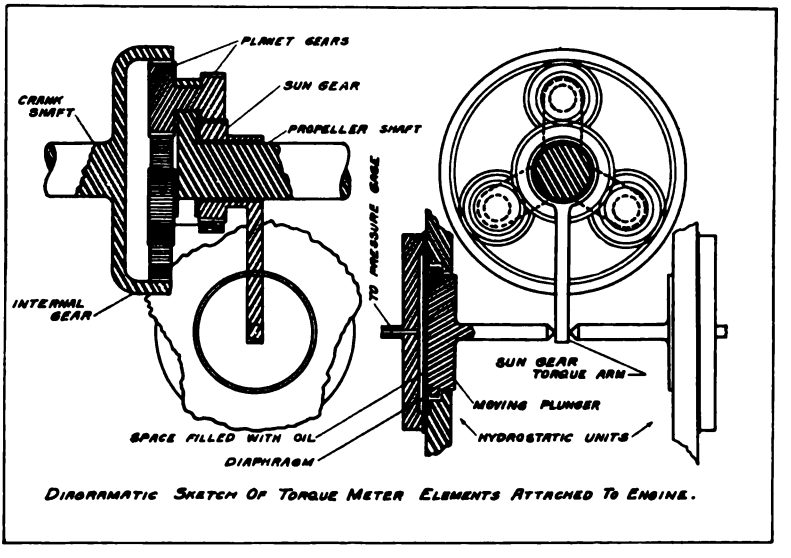

FIG. 1

The gear train in an epicyclic-geared Liberty engine consists of a large internal gear attached to the crankshaft, see figure 1.

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tended in this article to give a comprehensive summary of the Torque Meter and its functioning without becoming involved in too many computations and statistics. The Torque Meter is one of the outstanding developments of the Materiel Division, and too much credit cannot be given the personnel who are responsible for it.

Sincerely yours,
B. D. FOULOIS,
Brig. General, A. C.,
Chief of Division.

To: Major General J. E. Fechet, A. C.
Chief of the Air Corps.

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A spider, comprising the integral part of the propeller shaft, carries three equally spaced pairs of small planetary gears.

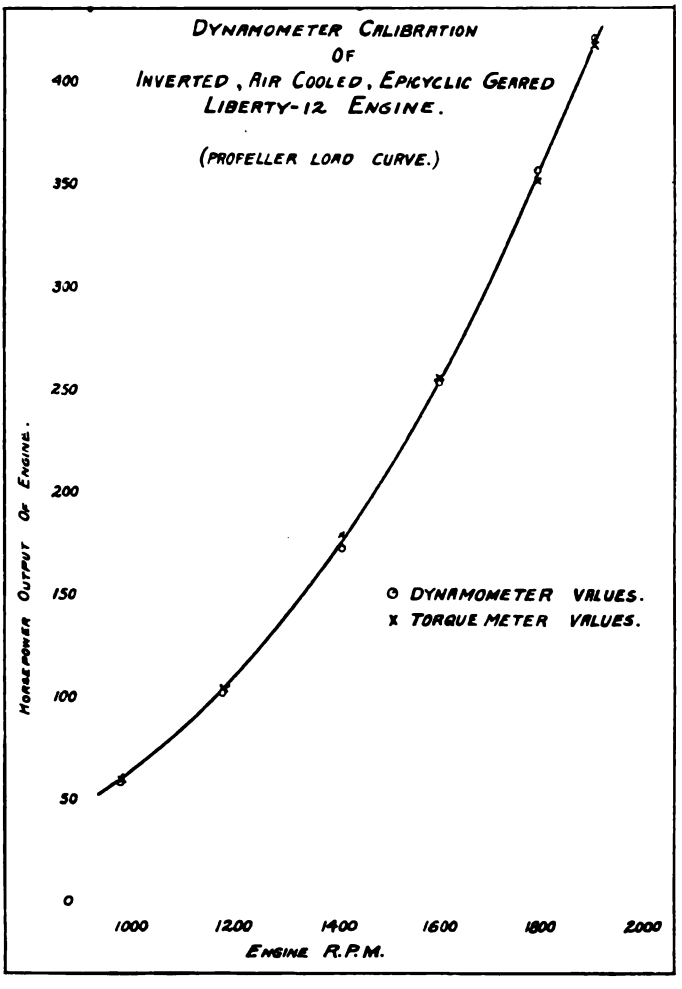

FIG. 2

The larger gear of each pair engages the internal gear on the crankshaft, while the smaller gear meshes with a sun-gear. The sun-gear, floating on the propeller shaft, is restrained from revolving

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by an auxiliary shock-absorbing unit which normally in epicyclic-geared Liberty engines is rigidly bolted to the gear case. (In figure 1 this shock-absorbing unit is not shown.) With this arrangement and the gear ratios used, the planetary system,

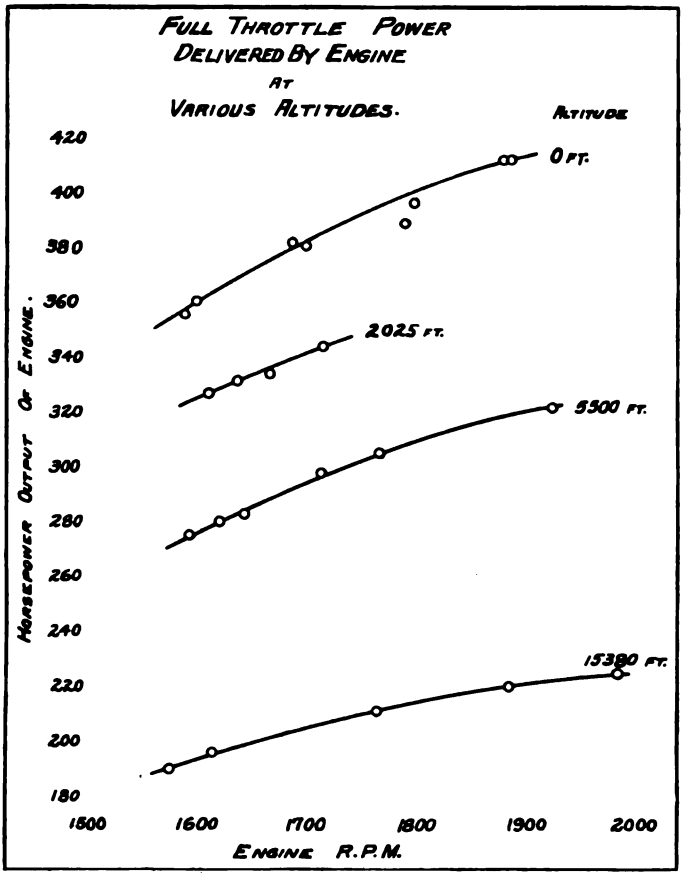

FIG. 3

and hence the propeller shaft, turns at three-fifths crankshaft speed.

In order to apply the torque-measuring method herein described, the sun-gear shock-absorbing unit, instead of being

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bolted to the gear case, was so constructed that it is free to rotate on a well lubricated journal bearing within the limits imposed by the weighing system. Through a special *torque arm* this

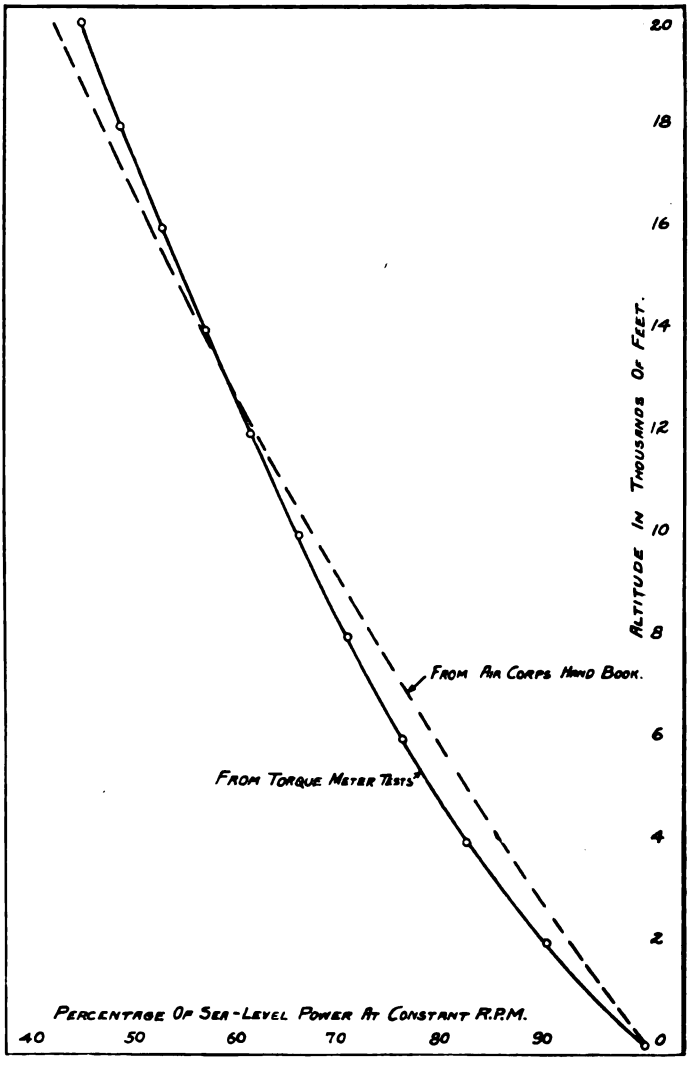

FIG. 4

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auxiliary part is restrained from turning by two unique hydrostatic units. One unit prevents rotation of the sun-gear in one direction, whereas the other unit keeps the sun-gear from turning oppositely.

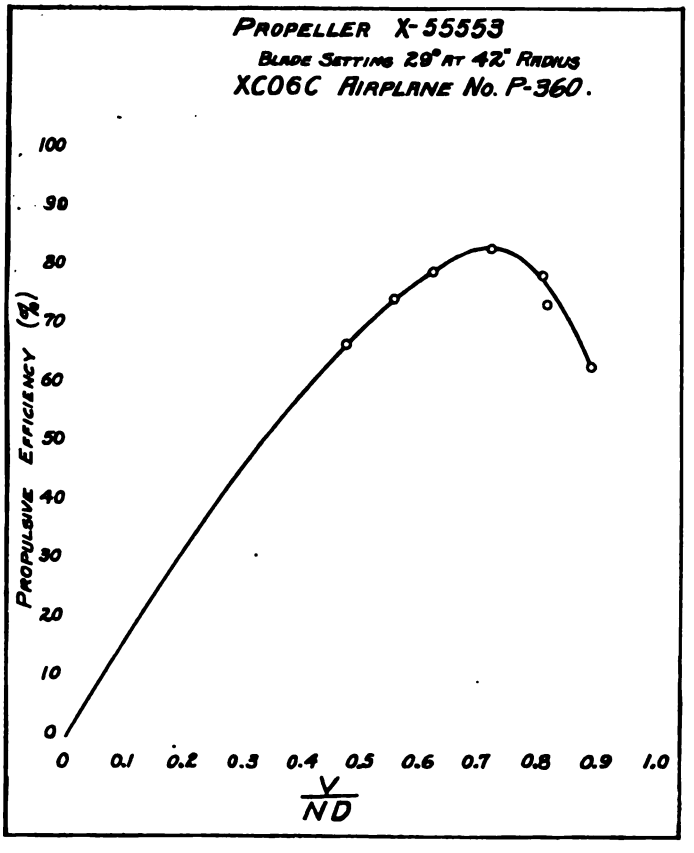

FIG. 5

Each hydrostatic unit consists essentially of a shallow circular chamber, the wall and back of which is one heavy piece of steel. The other side of the chamber is comprised of a thin metallic diaphragm tightly clamped around its periphery to the first piece of steel by means of a heavy steel ring and bolts. A spring-

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loaded plunger terminating in a disc that covers a large portion of the outside of the diaphragm applies sufficient extraneous force to counterbalance the initial pressure of the oil injected into the system of which the shallow chamber forms a part. Between the outer periphery of the plunger disc and the ring clamping the edge of the diaphragm is a steel annulus which reinforces the remaining surface of the diaphragm, but which is so arranged that

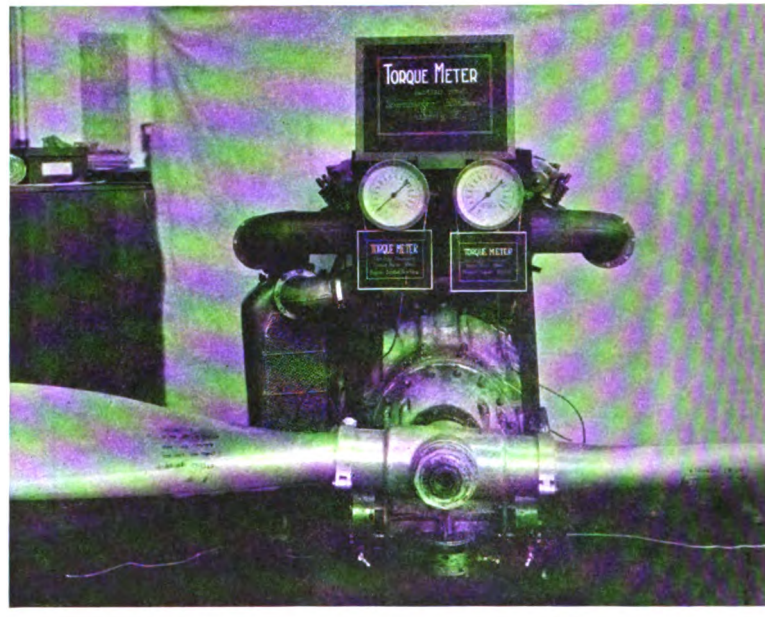

FIG. 6

it will interpose no appreciable opposition to the small movement required of the diaphragm. The pressure of the oil in the chamber is communicated through a small copper tube to a gage in the cockpit of the airplane. The gage is calibrated to indicate the pounds force exerted on the plunger by the torque arm. When sufficient oil is injected into the hydrostatic system by means of a pressure-gun to produce the proper initial pressure, the diaphragm assumes a neutral position and the gage scale and indi-

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cating pointer are adjusted to register "zero." Any additional force on the plunger causes the cockpit gage to indicate the value of this added force.

Two complete units like the one described above are employed on opposite sides of the torque arm so that, no matter which way the sun-gear tends to turn, the reactive force of the torque arm will be indicated on one or the other of the cockpit gages. A

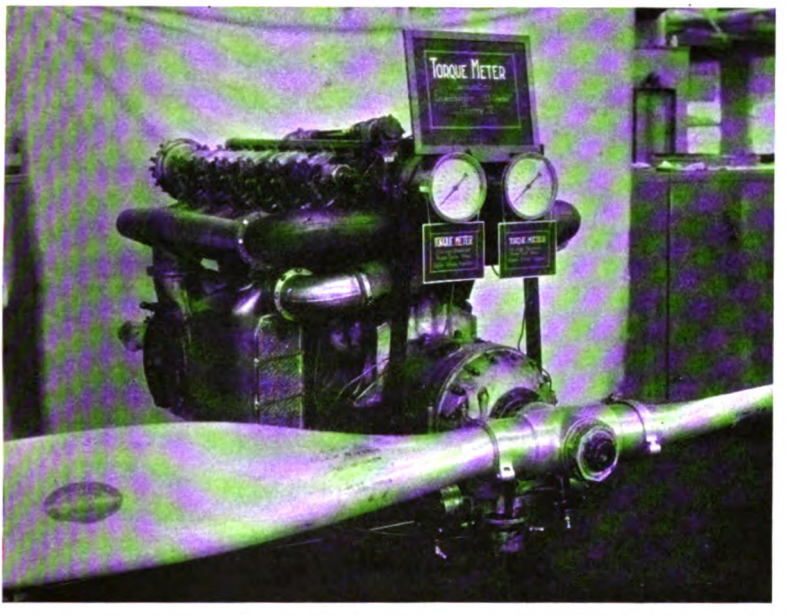

FIG. 7

force indication on one of the gages signifies a flow of power from the engine to the propeller, whereas an indication on the other gage denotes that the propeller, acting as a wind-mill, is supplying power to the engine.

There is a definite and constant known relation between the force acting at the end of the torque arm, as represented by the indication on the gage, and the corresponding torque required to turn the propeller. Knowing the corresponding speeds of rotation of the engine for various gage readings, the power flowing

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into or away from the propeller for each condition is easily computed. The power transmitted is determined by the formula,

$$\text{Horsepower} = \frac{\text{Net gage reading} \times \text{Engine r.p.m.}}{6000}$$

The term *net gage reading* is used above because the pressure of the oil in the system, and hence the gage reading, is susceptible to changes of temperature. Also the pressure at the gage will vary with the hydrostatic head of the effective oil column as the level of the torque reacting units changes above or below the initial level with respect to the gages. In order to know the necessary corrections to apply to the gage readings, a third duplicate

TABLE 1

CALIBRATION OF TORQUE METER ON ENGINE DYNAMOMETER WITH INVERTED AIR-COOLED LIBERTY ENGINE

ENGINE REVOLUTIONS PER MINUTE	DYNAMOMETER HORSEPOWER	TORQUE METER HORSEPOWER
1900	424	421
1790	361	356
1600	257	259
1410	175	179
1180	104	106
980	61	62

diaphragm unit is mounted near the two torque meter units, and is connected by a third copper tube to the cockpit gages.

Inside each of the two cockpit gages are two regular Bourdon type elements. The first element in one gage reacts to torque in one direction, whereas the first element in the other gage reacts to torque in the opposite direction. The second elements in the two gages are connected in common to the third hydrostatic unit above mentioned. Thus, in front of each dial is a pointer (red) that indicates quantitatively the correction, plus or minus, that must be applied to the indication of the other pointer (black) on the same dial to determine the true torque force.

Before installing in an airplane the first engine equipped with

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this torque meter, it was calibrated on an engine testing dynamometer in the power plant laboratory at Wright Field. The calibration was started at the rated power and speed of the engine (see table 1). As the speed was reduced to the various values, the power was adjusted so that it was proportional to the cube of the speed. This gave the values for the curve of figure 2, called a propeller load curve. It will be observed that the values of power determined from the torque meter readings agree very closely with those determined by means of the regular dynamometer equipment. The results being satisfactory, the engine equipped with the torque meter was installed in an airplane.

With this installation a rather bulky quantity of data was obtained for various conditions of flight and at numerous altitudes from sea level up to 20,000 feet. It is not the purpose of this paper to present the results of these torque meter flight tests, a summary of which may be found in *Wright Field Serial Report No. 3217*, but the results obtainable with the assistance of the torque meter are exemplified in figures 3, 4, and 5.

In figure 3 are presented values of full throttle horsepower actually delivered to the propeller at various speeds of revolution at altitudes of 0, 2025, 5500, and 15,380 feet. With but very few exceptions the observed values practically fall on the smooth curves as drawn in the figure.

The solid curve of figure 4 represents the power obtained at different altitudes in terms of the power obtainable at sea level with the same engine speed. The points marked along the curve are averages of values obtained with different engine speeds at the same altitude. The values of which each point is an average are very close together. The dotted curve is the one given in the "Handbook of Instructions for Airplane Designers," issued by the Materiel Division for general use in the estimation of airplane performance at altitude in the absence of more definite information relative to the particular engine that may be under consideration.

An efficiency curve for the propeller used in these tests is plotted in figure 5 for a blade angle setting of 29 degrees at the 42-inch radius. This is the net propulsive efficiency of the propeller

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plotted against V/ND in which V is the airplane velocity in feet per second, N is the revolutions per second of the propeller, and D is the propeller diameter (or length) in feet. The propeller of these tests, Design X-55553, is 13 feet in diameter.

The next move now contemplated, in fact in progress, is to conduct similar tests on an airplane powered by an engine equipped with a supercharger for high altitude duty. Instead of using the inverted air-cooled Liberty, however, it is necessary to use an upright water-cooled Liberty engine. The gearing is the same. Figures 6 and 7 show the upright, water-cooled, epicyclic-geared Liberty engine fitted with an exhaust gas-driven supercharger and the torque meter. The hydrostatic units appear in the figures just below the hub of the propeller. A larger propeller, probably 14 feet 6 inches in diameter, will be used for the altitude testing.

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THE WORK AND EQUIPMENT OF THE ASTRONOMICAL OBSERVATORY OF THE MARYLAND ACADEMY OF SCIENCES*

J. CARLTON WOLF, D.Sc.

Director of the Observatory

Go to yon tower, where busy science plies
Her vast antennae, feeling through the skies;
That little vernier, on whose slender lines
The midnight taper trembles as it shines,
A silent index, tracks the planets' march
In all their wanderings through the ethereal arch,
Tells through the mist where dazzled Mercury burns,
And marks the spot where Uranus returns.

—*Holmes.*

Impressed with the cultural value of astronomy, and mindful of the great popular interest in the science, the board of trustees of the Maryland Academy of Sciences more than two years ago authorized the purchase of a new refracting telescope. At the same time provision was made for housing the instrument in a modern astronomical observatory with revolving hemispherical dome, which would allow the sky to be viewed in any direction from the zenith to the horizon.

It has always been the desire of the trustees to foster the scientific spirit in the younger generation, and with this idea in view, every effort is being constantly made by the astronomical staff of the observatory to interest the pupils of the various city and state schools in the "wonders of the sky;" with the result that the attendance every clear Thursday evening, when the observatory is open to the public, now averages more than one hundred, exclusive of adults.

Classes from the different schools are received in groups, accompanied by their teachers or parents, and are allowed to look

* Received for publication May 28, 1930.

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through the telescope at the most interesting objects in view at the time. Explanations are also given of the objects being shown, and attention called to the utility of astronomy in ascertaining latitude and longitude on the earth's surface, and the relationship to navigation, as well as the determination of accurate time.

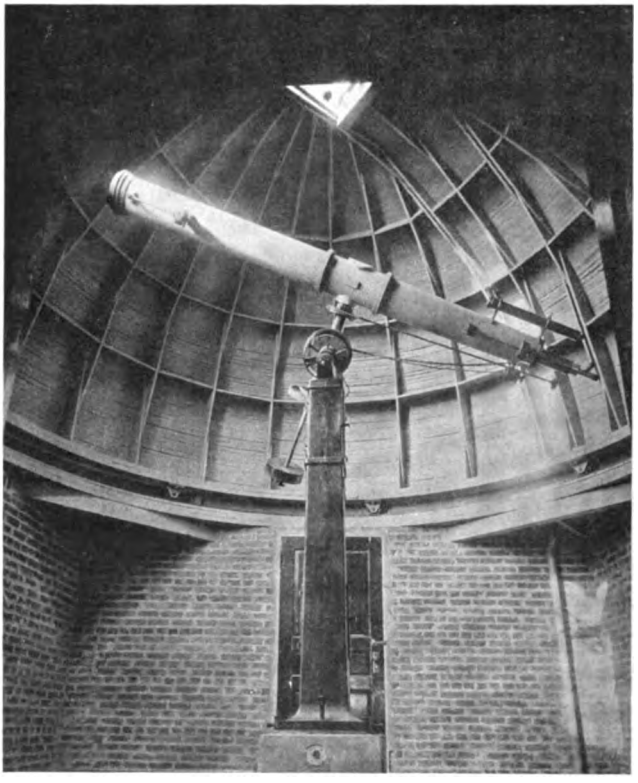

FIG. 1. THE INSIDE OF THE OBSERVATORY SHOWING THE TELESCOPE

The entire telescope, including mounting and optical system was constructed by the Alvan Clark & Sons Company of Cambridge Massachusetts. The object glass is of 8 inches clear aperture and 10 feet focal length and is the individual work of Mr. C. A. Robert Lundin, at the time, head of the optical department of the Clark firm. Mr. Lundin is world-famous for his optical skill, and has

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recently gained new renown by the construction of the photographic triplet lens, with which the trans-Neptunian planet was recently discovered at the Lowell Observatory.

Jena annealed glass was used in making both components of the objective and the finished lens has proven not only superb in defining faint planetary markings, etc., but also exceeds the theoretical limit of separating power for close binaries; and in

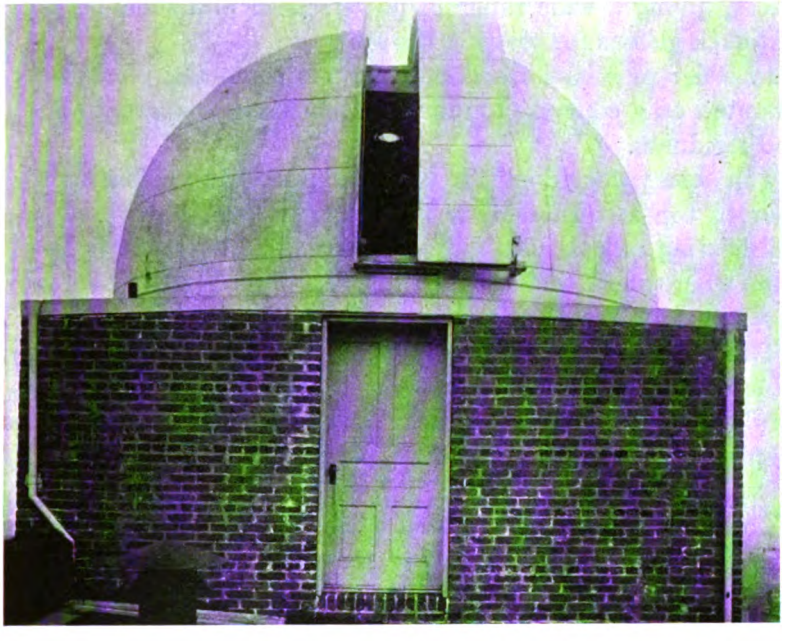

FIG. 2. THE REVOLVING HEMISPHERICAL DOME

addition shows faint stars fully a magnitude less than ordinarily visible with an instrument of this size.

The mounting is the new improved Clark equatorial type of steel pier, 8 feet, 4 inches in height, with the heavy castings and mechanical parts of enameled semi-steel and finely ground cone bearings. Other fittings, including graduated circles in both right ascension and declination for use in ascertaining the position of objects too faint to be located with the unaided eye are of

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heavily lacquered bronze. Slow motion screws of German silver actuated from the eye-end of the telescope are also included. A clock, electrically driven, enclosed in the pier compensates for the motion of the earth, and is controlled by a rheostat which allows its speed to be either accelerated or diminished. The telescope tube is made of rolled sheet steel, and carries a superimposed finder of 2 inches aperture and 20 inches focal length. The instrument is further equipped with a full battery of eyepieces, giving a wide range of powers; star and solar diagonals, and dark glasses for viewing the sun.

In order to secure freedom from vibration the pier has been mounted on a concrete foundation, which ensures great stability and rigidness.

The observatory dome, 16 feet in diameter and 17 feet high from floor to top is turned by a hand mechanism, and revolves on ball-bearing rollers. Adjoining the dome-room proper is another room where an astronomical library is provided, and which serves as a reception room for visitors.

The astronomical staff, in addition to furthering the diffusion of astronomical knowledge among visitors, also conducts a regular observing program, which falls into six general classes: (1) planetary, (2) solar, (3) lunar, (4) comet, (5) occultations, and (6) variable star.

The most important of these is the measurement of the long period variable stars. A great number of these observations have been made during the past year and published in the astronomical journals of the country, such as *Popular Astronomy* and the *Annual Report of the American Association of Variable Star Observers.*

Plans are also going forward for the development of celestial photography, utilizing both the Academy's 8-inch refractor and other equipment privately owned by some members of the astronomical staff.

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TRAVELING WAVES*†

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INTRODUCTION

An electromagnetic state manifesting itself as a distribution of potential and current propagated at a definite velocity along a transmission line, is called a traveling wave. These waves, originating from abnormal causes such as lightning discharges, arcing grounds, or switching operations, oftentimes reach exceedingly high voltages which are not only dangerous to the line insulation and to the connected apparatus; but also, by causing line-to-line and line-to-ground arcovers, precipitate system outages and discontinuity of service. The study of these waves has therefore become of critical importance to the transmission line engineer in order that ways and means could be devised for guarding against them, and protecting the system from their effects.

The advent, during the last few years, of reliable and practicable instruments for measuring and recording natural lightning waves on transmission circuits, such as the cathode ray oscillograph, klydonograph, surge recorder, direct hit indicator, and field gradient recorder, has added new impetus and incentive to the study of the theoretical aspects of traveling waves caused by lightning. The theory of traveling waves on transmission circuits was developed long before suitable experimental methods were available for its verification. The early investigators formulated the general differential equations, and obtained solutions for numerous different terminal conditions. But their examples were

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† Communicated by F. W. Peek, Jr., director of the high voltage engineering laboratory and engineer in charge of the general transformer engineering department, General Electric Company at Pittsfield.

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worked out for the case of an infinite rectangular wave, not only because the solution for such a wave is far easier to obtain than for any other wave shape, but also because it is the most severe wave in its effect on insulation, and because at that time nothing was definitely known as to the true shape of lighting waves. This early work was carried out in terms of conventional differential equations, which suffer tremendously in comparison with the symbolic methods of the operational calculus, when working with the traveling wave reflections and refractions. Finally, with the exception of a splendid paper by K.W. Wagner, hardly any attention was paid to the mutual effects between wires of a multi-conductor system. However, it is a fact that the simple single circuit theory of traveling waves is quite sufficient, both qualitatively and quantitatively, for most engineering purposes, and the more complicated multi-conductor theory need not be invoked except where there are discontinuities in the mutual effects.

Present day investigations of traveling waves are concerned with their origin, shape, attenuation and distortion as they travel along the line, behavior at a transition point where there is an abrupt change of circuit constants, mutual induction between conductors, and finally and ultimately, their effect on the insulation and power equipment or apparatus connected to the system. Research is being carried out in four closely coördinated ways: (1) research in the field by means of elaborately equipped lightning measuring stations, and recording instruments distributed along the transmission line, (2) study of high potential artificial lightning surges impressed on the line by means of lightning generators, (3) exhaustive tests on insulators and apparatus under controlled conditions in lightning laboratories, and finally (4) the inevitable theoretical and mathematical correlation. This article is primarily concerned with the last of these, and is in the nature of a semi-popular description of traveling wave phenomena.

ORIGIN OF TRAVELING WAVES

Lightning surges on transmission lines owe their origin either to a direct hit or induction.

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The direct lightning stroke may strike the line wire, or strike a ground wire and cause an accompanying traveling wave to appear on the line wires by induction, or it may strike the tower, and if the tower and its footing have a relatively high impedance, arc over to one or more of the line conductors. Potentials due to direct stroke may reach values of the order of 10,000,000 volts if the line itself is struck. However, by the proper design and location of a direct hit ground wire (or diverting wire as it is sometimes called), and by employing tower footing resistances of a sufficiently low value, it appears economically possible and feasible to protect the line conductors against excessive voltages due to direct hits on the tower or ground wires. From the data now available it may be stated that the traveling waves caused by lightning are predominately unidirectional. Those oscillograms which showed oscillations on the tail of the wave, had decreased to harmless values by the time that these oscillations appeared, so that from the point of view of danger to apparatus or line insulation, the waves were unidirectional.

Traveling waves due to induced strokes are far less dangerous than those due to direct strokes. The maximum potential at the point of origin of an induced wave, and the crest of the traveling wave are respectively:

$$V = \alpha G h$$
$$V' = \alpha' G h$$

where h is the height of the line conductor, G the field gradient, and α and α' factors depending on the law of cloud discharge and the distribution of bound charge (fig. 1). For an instantaneous cloud discharge (an impossible assumption) $\alpha = 1.0$ and $\alpha' = 0.5$. As the time of cloud discharge increases both α and α' decrease, and rapidly approach equality, so that for a cloud discharge slower than 10 microseconds, they are practically equal. The length of the wave is

$$L = x + t$$

where x is the length of the bound charge in thousands of feet, and t is the time of cloud discharge in microseconds, and the front of

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the wave is x or t depending upon which is the smaller. It is evident that induced strokes become harmless for longer periods of cloud discharge, and that high potential induced strokes are pos-

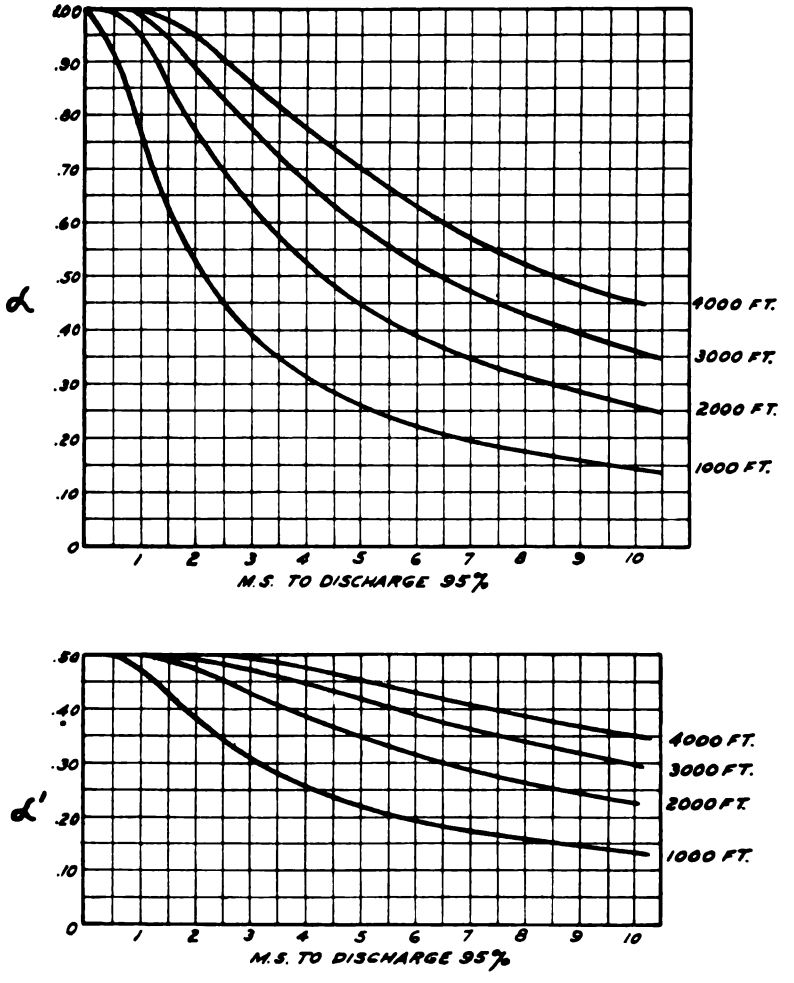

FIG. 1

sible only with very short waves. For the accepted maximum value of $G = 100$ kv/ft., an average line height of $h = 60$ feet, and a 3000-foot rectangular bound charge, the maximum induced

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traveling waves corresponding respectively to 5, 10 and 30 microseconds for the cloud to discharge, are

$$V_5' = \alpha'_5 Gh = 0.42 \times 100 \times 60 = 2520 \text{ kv.}$$
$$V_{10}' = \alpha'_{10} Gh = 0.30 \times 100 \times 60 = 1800 \text{ kv.}$$
$$V_{30}' = \alpha'_{30} Gh = 0.13 \times 100 \times 60 = 780 \text{ kv.}$$

Thus the dangerous induced surges are very short waves, and can occur only for extremely rapid rates of cloud discharge. Induced voltages are roughly halved by the use of ground wires; so that they can be readily taken care of on the higher voltage transmission lines, but may cause unavoidable outages on lines insulated for less than 100 kv.

The most feasible way of correlating the direct versus induced stroke arguments is through the simple theoretical relationships between the traveling waves originating from these two causes. The law of cloud discharge has a much greater effect on the shape of the traveling wave than the distribution of bound charge, and therefore the assumption of a rectangular bound charge may be made without involving any marked departure from the true shape of the traveling wave. Thus the determination of the wave shape reduces to the problem of finding the law of cloud discharge. If the wave measured by the cathode ray oscillograph station was due to a direct stroke, then the shape of the current wave in the lightning bolt is known. This current is

$$i = \frac{\partial Q}{\partial t} = Q_0 \frac{\partial}{\partial t} F(t)$$

where Q_0 is the total charge at the beginning of cloud discharge, and $F(t)$ is the law of cloud discharge. Therefore

$$F(t) = \frac{1}{Q_0} \int_0^t i \, dt$$

The actual numerical values of Q_0 and i are unimportant. All that is necessary is to arbitrarily choose Q_0 of such value that $F(t)$ reaches a final value of unity at the completion of cloud discharge, which is complete when i has ceased. In figure 2 are shown a few simple laws of cloud discharge, and the corresponding direct stroke

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waves and induced waves. Thus if a cathode ray oscillogram is definitely known to be that of either a direct or induced stroke, then the character of the other may be derived. Of course the length and shape of the bound charge distribution will influence the shape of the induced traveling wave, but not nearly to the same extent as the law of cloud discharge. The above expressions follow from the premise that the electrostatic field of the cloud collapses *uniformly*. Possibly there is considerable departure from this assumption. Nevertheless, the above equations do correlate

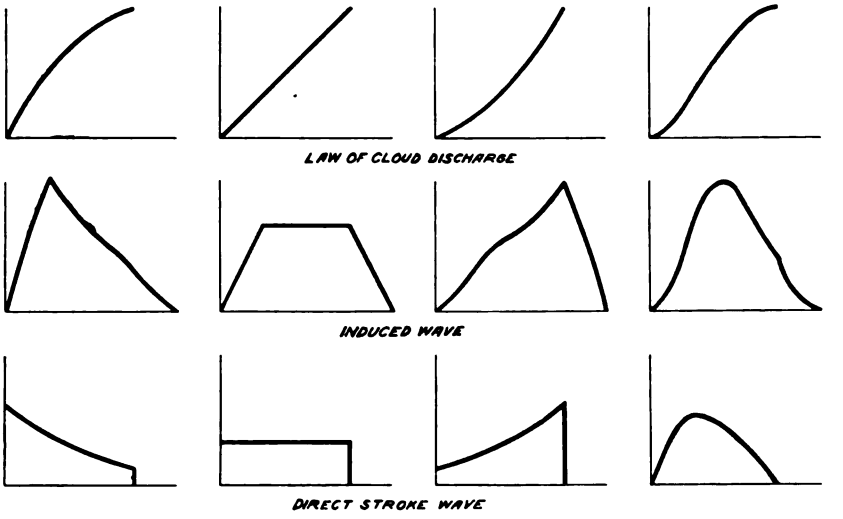

FIG. 2

the two types of lighting waves as near as our present knowledge of the mechanism of cloud discharge will permit.

SHAPE OF TRAVELING WAVES

An examination of the cathode ray oscillograms of natural lightning waves which have been obtained during the past few years, discloses that the most of them are of relatively simple shape, although nearly all of them are serrated by minor irregularities. However, the principal features of the wave shapes caused by natural lightning are included in figure 3, that is, may be repre-

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sented by the difference of two exponentials. This is an extremely fortunate situation, since calculations of the effect of traveling waves on terminal equipment is more easily carried out for exponential components than for any other wave shape, except the infinite rectangular wave. So many of the cathode ray oscillograms have the same general outline as figure 3D that it is probably permissible to speak of that shape as the typical lightning

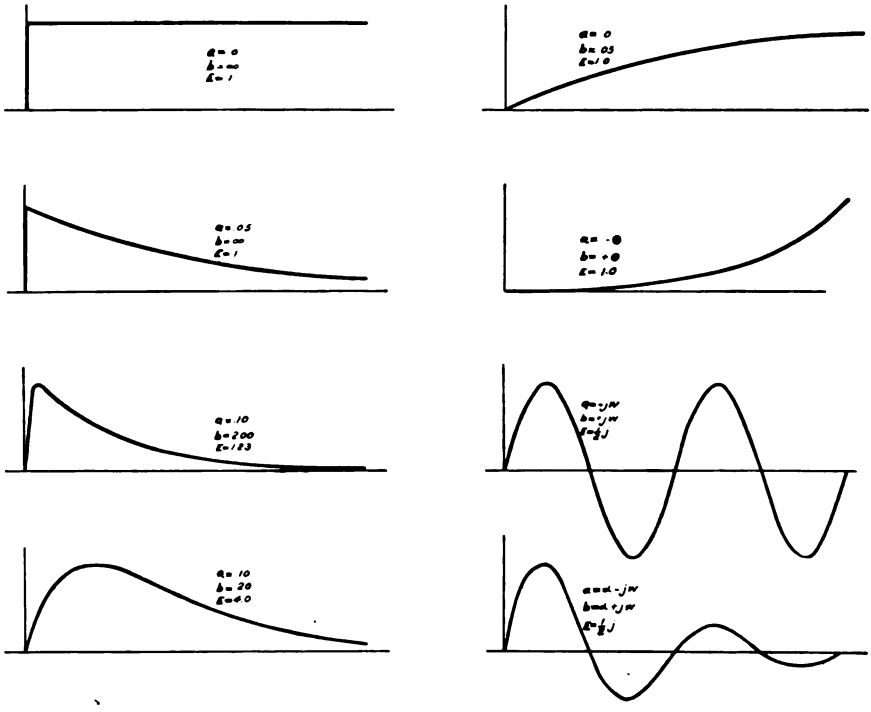

FIG. 3

wave. A traveling wave is characterized by four specifications. The *crest* of the wave is its maximum amplitude. The *front* is that part of the wave from the beginning to the crest. The *tail* is that portion of the wave behind the crest. The *polarity* of the wave is the polarity of the crest, or in the case of an oscillatory wave, is given as the polarities of successive loops. Practically, in designating a wave, it has become customary to disregard that part of

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the tail beyond the point at which the wave has decreased to half value. Thus in speaking of a wave as 20 ms long it is understood that the length of the wave to the 50 per cent value on the tail is 20 ms. For brevity, a 750 kv. positive polarity wave with a 3.5

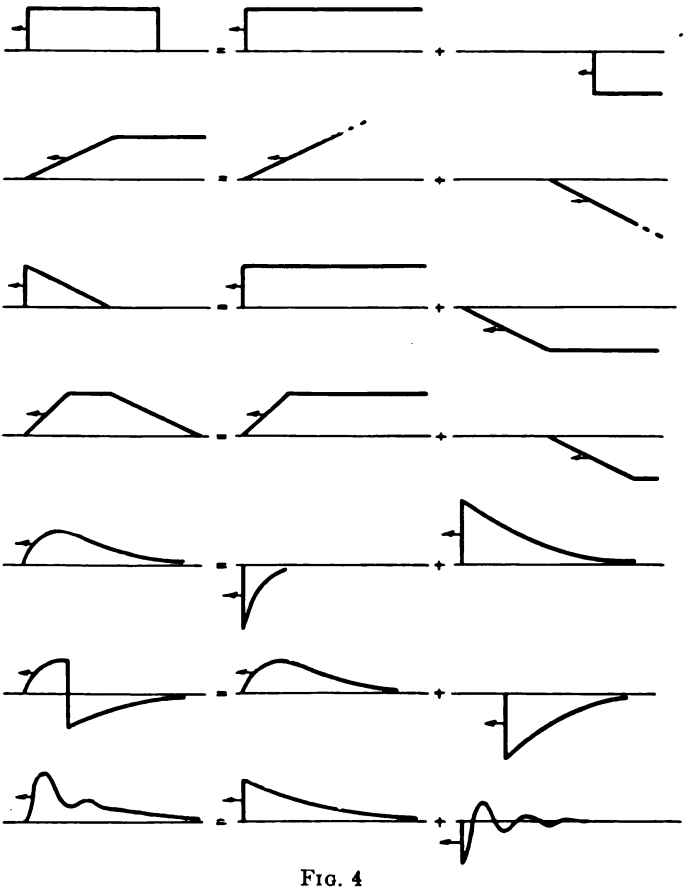

FIG. 4

ms front and a 22 ms tail (to the 50 per cent point) may be designated by 750 kv./3.5/22/+.

When a wave shape is too complicated to be represented by the difference of two exponentials, possibly it may be formed by compounding waves as illustrated in figure 4. In any event, it can

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always be approximated to any required degree of accuracy by the use of a sufficient number of rectangular components, as shown in figure 5. There is a mathematical expression, called Duhamel's Theorem, by means of which the solution corresponding to a wave of any shape may be obtained if the solution for an infinite rectangular wave is known, and if the necessary integration can be performed. This theorem is the analytical counterpart of the graphical representation in figure 5.

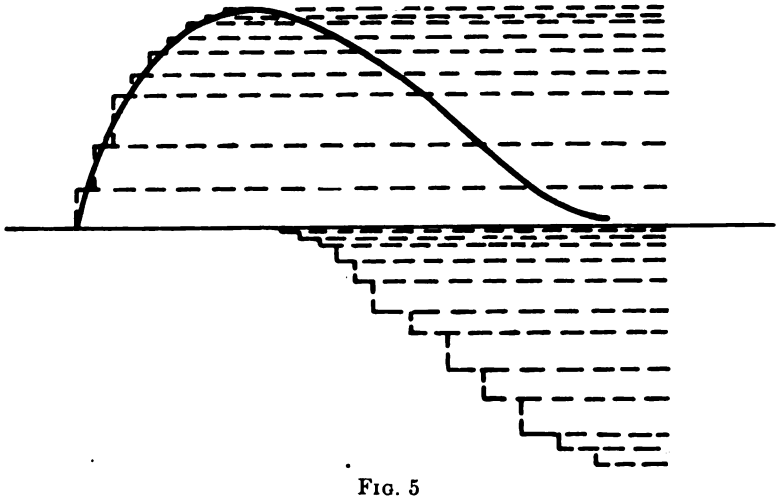

FIG. 5

ATTENUATION OF TRAVELING WAVES

It is usually justifiable to consider traveling waves as pure distortionless waves, and then to compensate for the attenuation by an exponential decrement factor. This factor is generally arrived at experimentally for a given line and conditions. However, the attenuation seems to be a rather unsettled thing, and varies not only with the voltage and shape of the wave, but also appears to be sensitve to weather conditions. Experiments with artificial lightning waves have demonstrated that there is no such thing as a definite attenuation on a given line. Moreover, certain effects have been charged up to line attenuation which are not properly allocated as such. For instance, if a direct stroke of lightning

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strikes a ground wire, which is grounded at the towers through fairly high resistance, then a wave may travel on the ground wire for a considerable distance before it is dissipated by losses principally in the tower resistance. But there are accompanying waves induced on the line wires, and these waves decrease with the parent wave on the ground wire. Surge recorders connected at intervals along the line wire would record a rapidly diminishing surge, and if it were not known that this measured surge was due to induction from a traveling wave on the ground wire, it would be inferred that the line had an extremely high attenuation.

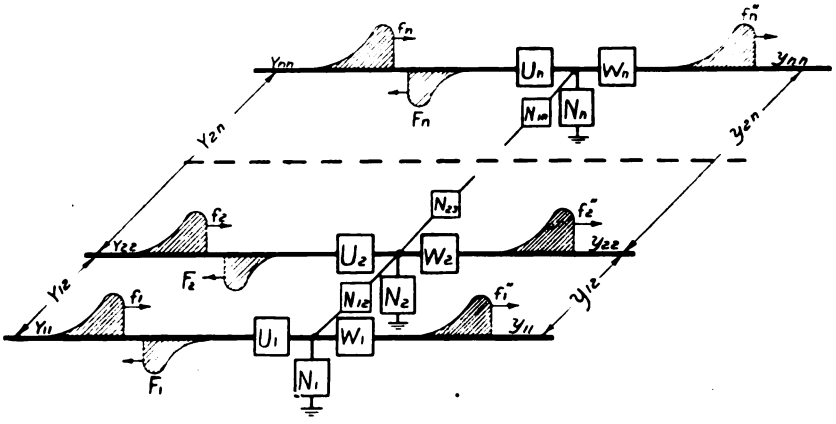

FIG. 6

Corona is the chief factor in causing the attenuation of lightning waves. Its effect in leveling off the top of a high potential surge is illustrated pictorially in figure 8. Transient skin effect is the second most influential factor in causing attentuation. The calculation of transient skin effect is difficult, and to the author's knowledge there are no reliable experimental data in support of the theory. Ground wires appear to have some influence on attenuation, causing a few per cent decrease for surges of negative polarity, but not changing that of positive surges appreciably. In any event, the effect of corona is so much more pronounced, that there is little need to consider the other factors affecting attenuation.

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Figure 9 shows the effect of attenuation in the charging of an open-ended line from an infinite voltage source. Without losses, the cycle of oscillations repeats indefinitely but when line losses are present the oscillations gradually diminish until eventually the line reaches a steady state condition. However, a distortionless line can never become fully charged to the terminal potential throughout its length, for the distortionless feature requires the presence of both leakage conductance and series resistance. The flow of current in the leakage conductance results in a progressive voltage drop along the line. Therefore, the ultimate level charging of a line requires that there be no leakage currents.

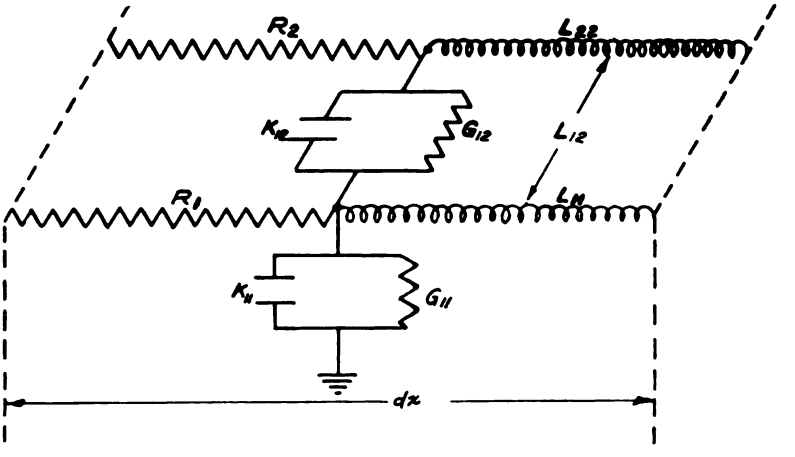

FIG. 7

GENERAL PROPERTIES OF TRAVELING WAVES

If a line is free from losses, that is, if corona, skin effect, conductor resistance, leakage conductance to ground and between conductors, and earth resistance can all be neglected, then the differential equations of the system are satisfied by pure wave functions. These waves travel without attenuation or distortion until a transition point on the circuit is reached, where they reflect and refract in accordance with the general laws of traveling wave theory. In an n-wire no-loss system there are n possible

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velocities of wave propagation, but in the case of overhead conductors these n velocities all become equal to the velocity of light.

If the line is completely transposed, so that every conductor occupies the same relative position as every other conductor and for the same distance, then the possible average velocities between terminals are reduced to two in number. If the line is made up of g groups, and the conductors of each group are completely transposed with respect to their own group, then there are $(g + 1)$ possible average velocities.

The conventional method of calculating the steady state alternating current behavior of a transmission line by using "constants to neutral" is a very special case, but is rigorous for a single circuit, three phase, completely transposed line. To obtain these

FIG. 8

simplified equations directly from the general alternating current solution is a matter of considerable manipulation.

In an n-wire circuit the energy of free traveling waves is equally divided between the electrostatic and the electromagnetic fields. However, when these waves reach a transition point, or when waves traveling in opposite directions pass through one another, the energy balance is upset. Whether the energy resides mostly in one field or the other during a transition period depends entirely upon the nature of the transition. For instance, in the simple case of a wave striking the open end of a line, the energy shifts to the electrostatic field. If the wave happens to be rectangular the entire energy resides in the electrostatic field for a period equal to half the wave length. Conversely, for a grounded line the shift of energy is to the electromagnetic field. If the line is grounded through a resistance equal to the surge impedance of the line, the energy is completely dissipated as heat.

The effect of line losses on traveling waves is three-fold: (1)

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the voltage and current waves decrease in amplitude, or are attenuated, (2) the shape of the waves is distorted with time, and (3) the current and voltage waves depart from exact similarity

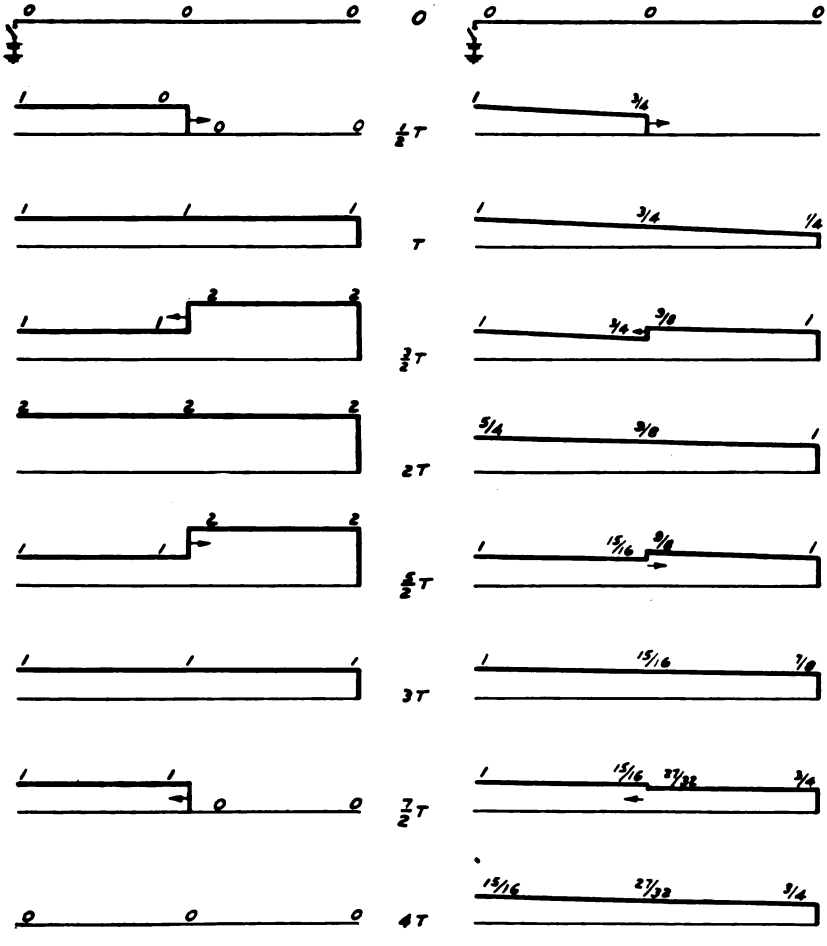

FIG. 9

so that they are no longer connected by the simple linear proportionality factors called the self and mutual surge impedances of the line. However, numerous field tests with artificial lightning waves on transmission lines have shown that the principal shape

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(that is, ignoring the minor irregularities) of a traveling wave is not seriously distorted unless far above the corona limits of the line. Thus the behavior of waves may be computed with good engineering accuracy by treating them as pure distortionless waves, and compensating for their attentuation by simple exponential decrement factors. If, however, the waves are decidedly above the corona limits, then the corona losses literally slice off their tops, or that portion of the wave above the corona limit as shown in figure 8. The rest of the wave arrives without having suffered much change, except in the case of a wave with an exceedingly steep front, say 1 microsecond. Such a front will be considerably reduced in steepness. It should be observed, that since the effect of the losses is to reduce the severity and danger range of a wave, that calculations which ignore the losses err on the side of safety. This is usually sufficient justification for calculating traveling waves due to lightning by the equations of either a *no-loss* or a *distortless* line.

Pure traveling waves of voltage and current on an n-wire system, are related to each other by a set of simultaneous linear equations having constant coefficients called the self and mutual surge impedances of the line. These equations, are

$$\begin{aligned}
\pm e_1 &= z_{11}i_1 + z_{21}i_2 + \ldots\ldots + z_{n1}i_n \\
\pm e_2 &= z_{12}i_1 + z_{22}i_2 + \ldots\ldots + z_{n2}i_n \\
&\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\
\pm e_n &= z_{1n}i_1 + z_{2n}i_2 + \ldots\ldots + z_{nn}i_n
\end{aligned}$$

where the $(+)$ sign is used for waves traveling in the forward direction, and the $(-)$ sign for waves moving in the reverse direction. Also, for overhead conductors,

$z_{rr} = 60 \log \dfrac{(2h)}{r}$ = self surge impedance of conductor r

$z_{rs} = 60 \log \dfrac{a}{b}$ = mutual surge impedance between r and s

h = height of r above ground place
a = distance between r and image of s
b = distance between r and s
r = radius of conductor

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Instead of writing the voltages in terms of the currents and the surge impedances, the arrangement may be reversed and the currents written in terms of the voltages and surge admittances as follows:

$$\pm i_1 = y_{11}e_1 + y_{21}e_2 + \ldots\ldots + y_{n1}e_n$$
$$\pm i_2 = y_{12}e_1 + y_{22}e_2 + \ldots\ldots + y_{n2}e_n$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$\pm i_n = y_{1n}e_1 + y_{2n}e_2 + \ldots\ldots + y_{nn}e_n$$

These equations, in conjunction with the principle of superposition and the conditions of voltage and current continuity at a junction or transition point, define the behavior of pure traveling waves on transmission systems. The principle of superposition is involved in calculating the effect of more than one independent wave at the same point simultaneously, such as occur for successive reflections, meeting of circuits, etc.

In the majority of problems dealing with traveling waves, it is sufficient to make the calculations on the basis of a single wire circuit. The return part of the circuit may be either a second conductor or the ground.

The presence of adjacent conductors may be ignored if they possess no circuit discontinuities and if the initial wave was applied only to the conductor under consideration, or if similar waves were applied simultaneously to the other wires, except in so far as the surge impedance of the conductor under consideration is effected by the adjacent conductors. For this reason many practical problems can be reduced to a simple, single circuit, traveling wave problem. It is surprising how many situations may be represented in that respect, and the excellent agreement that can be obtained between calculations and test with artificial lightning waves and cathode ray oscillograph.

When the single circuit theory is applicable, the potential and circuit waves are proportional to each other by the surge impedance of the circuit:

$$e(x - vt) = \quad Z.i\,(x - vt) \text{ for forward moving waves}$$
$$e(x + vt) = -\,Z.i\,(x + vt) \text{ for backward moving waves}$$

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where

$Z = \sqrt{L/C}$ = surge impedance in ohms
$Y = 1/Z$ = surge admittance in mhos
L = inductance in heneries
C = capacitance in farads

It is to be noticed that for waves traveling in the positive or forward direction that e and i have the same sign; but that for waves traveling in the reverse or negative direction they have opposite signs. However, it is immaterial which direction along the line be chosen as positive or forward, provided that the positive sense be strictly adhered to throughout the calculations.

The reflection and refraction operators are

$$\frac{Z_0 - z}{Z_0 + z} \text{ and } \frac{1}{1 + N(W + z)} \frac{2z}{Z_0 + z}$$

where Z_0 is the total impedance, expressed in operational form, at the transition point as viewed from the approaching incident wave, z is the surge impedance of the line, and N and W are impedances having the same meaning as in figure 6. When these operators are applied to any incident wave e, expressed as a function of time t counted from the instant that e arrives at the transition point, they derive the reflected and transmitted waves e' and e'' respectively. As an example of their application, consider a choke coil or reactor connecting a line to another line or cable, and let the incident wave approaching from the left be

$$e = E\epsilon^{-\alpha t}$$

Then

$z = z_1$ = surge impedance of incoming line
$Z_0 = z_2 + pL$ = total impedance to the right
$N = 0$ = shunt admittance
$W = pL$ = series impedance

and let

$$\alpha = (z_1 - z_2)/L$$
$$\beta = (z_1 + z_2)/L$$

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Therefore

$$e' = \frac{Z_0 - z_1}{Z_0 + z_1} E\epsilon^{-at} = E\epsilon^{-at}\frac{p+\alpha-a}{p+\beta-a} = E\left[\frac{a+\alpha}{a-\beta}\epsilon^{-at} - \frac{\alpha+\beta}{a-\beta}\epsilon^{-\beta t}\right]$$

= reflected wave

$$e'' = \frac{2Z_1}{Z_0 + z_1} E\epsilon^{-at} = E\epsilon^{-at}\frac{1}{p+\beta-a} = E\frac{\alpha-\beta}{a-\beta}\left[\epsilon^{-at} - \epsilon^{-\beta t}\right]$$

= transmitted wave

TERMINAL EQUIPMENT AND THEIR EQUIVALENT CIRCUITS

The typical transmission system comprises lines, cables, ground wires, switches, buses, insulators, bushings, lightning arresters, reactors, transformers, generators, coupling capacitors, etc. Therefore, in order to calculate the behavior of traveling waves on such systems, it is necessary to know the high frequency characteristics of these equipments and the equivalent circuits which represent them. By fortunate circumstances, the *external* reaction of system apparatus to traveling waves can be computed with excellent engineering accuracy by using very simple equivalent circuits. However, to compute the *internal* oscillations of transformers, generator windings, etc., it becomes necessary to use the much more complicated distributed circuit constants (self and mutual inductance, series and shunt capacitance) of these apparatus. Figure 10 shows the ideal and external equivalent circuits of transformers, rotating machines, and reactors.

When a traveling wave strikes a transformer it encounters a relatively small capacitance, which is quickly charged, so that after the first microsecond or so the terminal conditions are substantially the same as for an open line, with the resulting doubling up of voltage by the positive reflection. Thus the transformer itself does not have an appreciable effect on the external wave, so that it is usually sufficient to calculate the internal oscillations caused by a traveling wave on the asumption that the terminal voltage is not affected thereby. These internal oscillations consist of a number of space harmonics vibrating at rates approximately proportional to the square of their order. Thus the maximum envelope of oscillation does not occur at the

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terminal, but at some intermediate point along the stack. In the case of a transformer with a grounded neutral, the peak of the oscillation is located about 25 per cent from the line terminal, and for steep wave fronts may reach values as high as 60 per cent in excess of the applied terminal voltage. The peak of oscillations is close to the neutral, if it is isolated, and approaches 200 per cent line voltage. When impedances are used in the neutral, the peak of oscillations lies intermediate between its value for

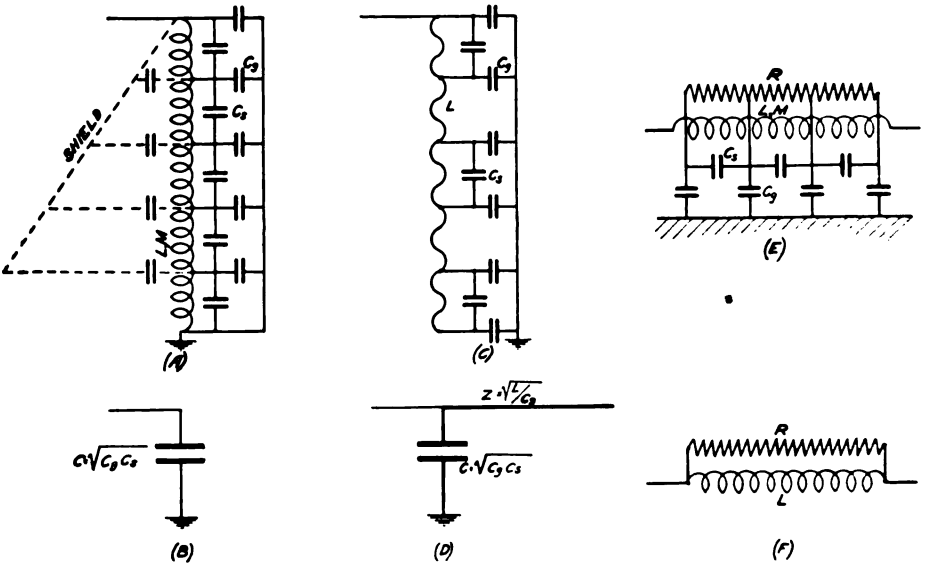

FIG. 10

grounded and isolated neutral conditions. If the applied wave is oscillatory with a frequency in the neighborhood of one of the natural frequencies of oscillation of the transformer, then there is danger of resonance, and internal voltages of the order of four times the applied voltage are obtained. However, the employment of a properly designed electrostatic shield in the so-called *non-resonating* type of transformer has made it possible to practically eliminate internal oscillations of all kinds, whether due to steep wave fronts or oscillatory waves of any frequency. Practical advantage has been taken of this principle both by increas-

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ing the margin of safety against abnormal voltages, and by grading the major insulation in proportion to the normal frequency voltage stresses.

A rotating machine, as generator or synchronous condenser, differs from the transformer in its high frequency characteristics, in that its series capacitance and mutual inductance circuits are interrupted, and it therefore behaves more like a short transmission line. The principal features of the internal oscillations of a rotating machine winding can accordingly be calculated as successive reflections on a short line.

A reactor in a line or cable terminating at a transformer or bus, may cause a severe external oscillation to occur when struck by a traveling wave, for its inductance enters into oscillation with the capacitance of the transformer or bus. However, these oscillations do not occur if there are several other feeders connected to the bus, or if the reactor is shunted by a suitably designed resistor.

The sparkover characteristics of line insulators, bushings, and needle gaps, when subjected to traveling waves, are given by equations of the form

$$e = e_0\left(1 + \frac{a}{\sqrt{t}}\right)$$

where

e_0 = ultimate d-c sparkover voltage
e = impulse sparkover voltage
t = time of sparkover
a = characteristic constant depending upon type of gap, shape of wave, polarity, etc.

This equation is valid only up to particular limiting values of t, beyond which sparkover does not occur. For very short times, say a microsecond or so, the impulse voltage may be two or three times the ultimate d-c sparkover value, but the curve drops considerably in the first few microseconds. These characteristics are of great importance in connection with the study of the coördination of system insulation, so as to insure that the more easily repairable and accessible parts of the system will protect the successive links in the order of their importance.

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SUCCESSIVE REFLECTIONS

There are many important problems, such as in the theory of ground wires, the effect of short lengths of cable, trunk lines tapped at short intervals, etc., where it is necessary to consider a number of successive reflections of traveling waves. Sometimes it is exceedingly difficult to keep track of the multiplicity of these reflections. A lattice has therefore been devised which shows at a glance the position and direction of motion of every incident,

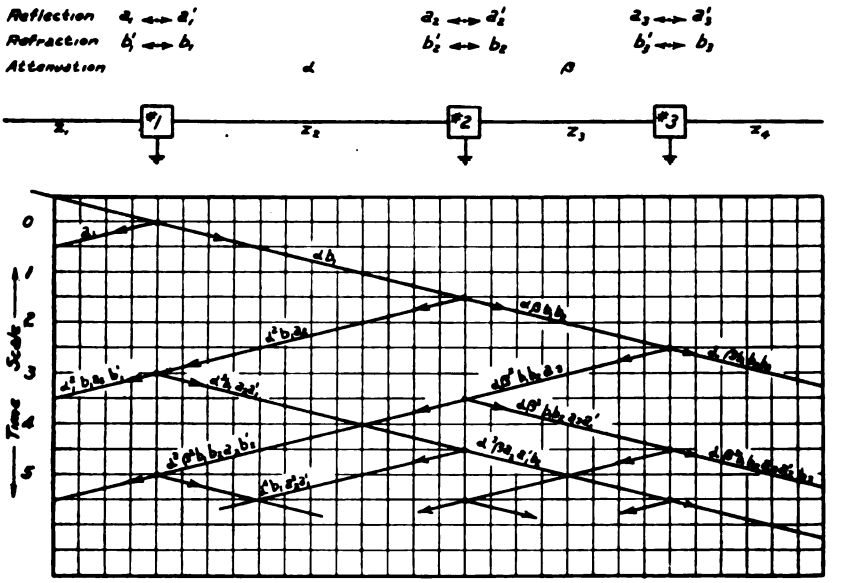

FIG. 11

reflected and refracted wave on the system at every instant of time. In addition, this lattice provides the means for calculating the shape of all reflected and transmitted waves and gives a complete history of their past experience. Even the effects of attenuation and wave distortion can be entered on the lattice, if the defining functions are known.

The principle of the reflection lattice is illustrated in figure 11. Three junctions, Nos. 1, 2, and 3 placed at uneven intervals along the line are shown. These junctions may consist of any com-

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binations of impedances in series with the line or shunted to ground. The circuits between junctions may be either overhead lines or cables; having, in general, different surge impedances, velocities of wave propagation, and attenuation factors. To construct the lattice, lay off the junctions to scale at intervals equal to the times of passage of the wave on each section between junctions. Now choose a suitable vertical time scale, shown in figure 11 at the left of the lattice, and draw in the diagonals. At the top of the lattice, at any convenient place centered on the junctions, place indicators with the reflection and refraction operators marked on them. In the notation of this paper these indicators are shown as little double-headed arrows marked as follows:

a = reflection operator for waves approaching from the left.
a' = reflection operator for waves approaching from the right.
b = refraction operator for waves approaching from the left.
b' = refraction operator for waves approaching from the right.
α, β = attenuation factors for section between junctions.

It is understood, of course, that these operators are operational expressions involving the impedance functions of the junctions, and no restrictions are placed on their generality. Now, starting at the origin of the initial incident wave at the top of the lattice, obtain the reflected and refracted wave at each junction by applying the operators of that junction to the incident wave arriving there, and proceed until the lattice has been completed. It will be observed that:

(1) All waves travel downhill.
(2) The position of any wave at any time is determined from the vertical time scale at the left of the lattice.
(3) The total potential at any point at any instant of time is the superposition of all the waves which have arrived at that point up until that instant of time, displaced in position from each other by intervals equal to the instants of their time of arrival.
(4) The previous history of any wave is easily traced, that is, where it came from and just what other waves went into its composition.

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(5) Attenuation is included.

(6) If it is desired to carry the computations to a point where it is not practical to place the various operators directly on the lattice itself, then the arms may be numbered and the operational expressions tabulated in a suitable table. No difficulty is encountered in this practice, and sometimes it is possible to devise purely tabular methods which can be filled in automatically.

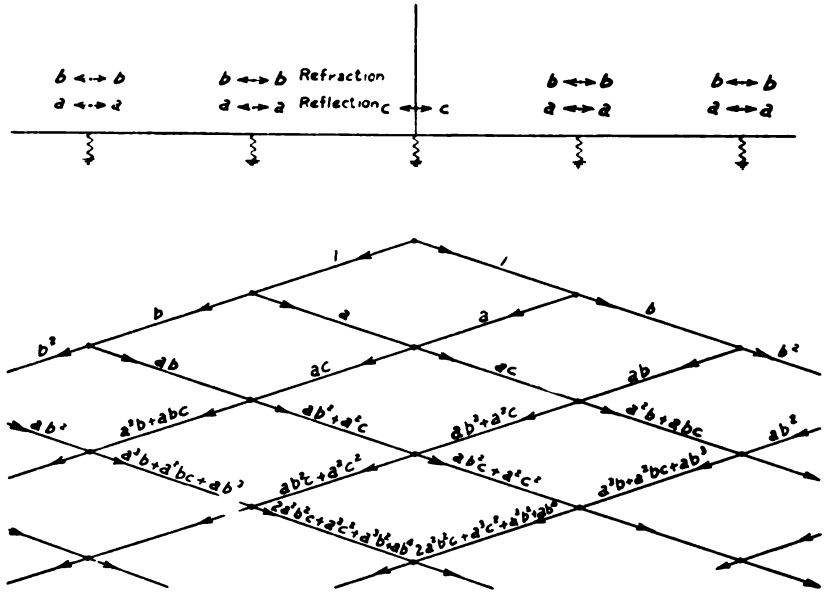

FIG. 12

Figure 12 illustrates the application of the lattice to the case of a direct lightning stroke striking ground wire at the tower. At each tower, where the ground wire is grounded through the resistance of the tower and its footing, reflections take place. The accompanying waves induced on the line wires do not affect the parent wave on the ground wire, so that their presence may be ignored. In this case the reflections and refractions are the same at all the towers except the one struck. A much more complete analysis of ground wires periodically grounded through resist-

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ances, including elaborate lattices, has been given in a previous paper. (Critique of Ground Wire Theory.)

Figure 13 shows another simple application of the lattice. The point of interest in this illustration is that there are two waves arriving simultaneously at the fifth instant, so that a doubling of voltage at that instant would be expected. This has been verified experimentally.

These examples, while simple and straightforward, will suffice to point out the wide field of usefulness and general applicability of lattices.

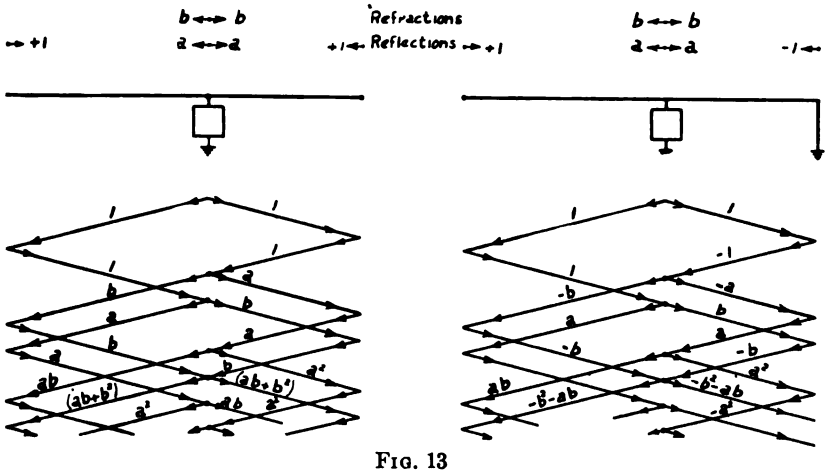

FIG. 13

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AVIGATION*[1,2]

Some Non-technical Observations on the Present Status and Trend of Development of Avigation

ALBERT HEGENBERGER

Lieutenant, Air Corps, U. S. A.; Navigator on the first non-stop flight from San Francisco to Hawaii

Not being endowed with an accurate instinct of direction and distance, man must depend on artificial aids when flying from point to point on the earth's surface. These aids take the form of natural and artificial landmarks that have been located on maps and instrument and radio means for determining direction and distance.

The layman examining the instrument board and cockpit

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[1] Communicated by Major-General James E. Fechet, Chief of the Air Corps, U. S. A.

[2] WAR DEPARTMENT

AIR CORPS

MATERIAL DIVISION

Wright Field, Dayton, Ohio.
September 26, 1930.

MAJOR-GENERAL J. E. FECHET, A. C.,
The Chief of the Air Corps,
Washington, D. C.

MY DEAR GENERAL:

I am enclosing an article for the JOURNAL OF THE MARYLAND ACADEMY OF SCIENCES, in accordance with your request of September 5, 1930. The subject of the article is "Avigation." This word has come into general use and is more logical than "Aerial Navigation;" also the word came into general practice at the Division and has since been used extensively outside. The present article constitutes observations on the status and trend of development in avigation and it is believed it will be of interest to many who are concerned in flying.

Sincerely yours,
(Sgd.) H. C. PRATT,
Brig. General, Air Corps.

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equipment of a present day air liner or military airplane cannot help but be impressed by the elaborateness and intricacy of the installation. Due to greater and greater results being demanded from the airplane, the number of instruments required for its effective operation when engaged on scheduled passenger-flying or military operations have increased steadily.

The safe and efficient operation of modern aircraft engines has required the addition of new instruments such as thermocouple thermometers for obtaining the temperature of cylinder heads and walls. For supercharging, the pilot must have gages showing the absolute pressure at the carburetor air-intake and the fuel-pressure to the same point. Due to the numerous and increasing demands for electricity on the airplane for navigation, landing and cockpit lights, radio, bombsights, gun synchronizers, etc., there is installed an electric power plant driven from the engine. The electric generator in turn requires voltmeters, a ımeters and voltage regulators for proper control. While all of these instruments are not strictly speaking for aviation purposes they nevertheless have a profound effect on the design and grouping of avigation instruments in that they use up the limited available space in the pilots cockpit. Because of this congestion designers are constantly striving to make all aircraft instruments as small and light as is consistent with accuracy and readability. The congestion furthermore limits the number, location and type of avigation aids.

With the exception of extensive flights over water, practically all cross-country flying has been of a type described as landmark pilotage. In this country where nearly all the terrain has been accurately mapped, pilots have been able to proceed to their destination by checking railroads, rivers, cities, mountains, lakes, etc., using a rough compass course between.

The great expansion of commercial aviation in the last few years has led to the development by the Department of Commerce of well organized airways. On these airways additional distinctive landmarks, such as marked roofs and intermediate landing fields and rotating beacons, have been installed. Except for radio aids discussed later, the tendency in commercial aviation

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is to reduce avigation to following guide posts in the form of landmarks. This is even more apparent when one also considers how a pilot flying the same route constantly becomes familiar with details not mapped.

The aim, in other words, is for the pilot to find his way, as far as possible by sight, supplemented by the radio beacon. In this manner he is freed from the necessity to make difficult measurement of his course and speed relative to the ground.

The system of avigation being developed for commercial airways does not meet the military needs for war time. For patrol and bombing flights long distances at sea or for operations over land areas at night with all lights darkened, a greatly different practice must be followed. Radio direction finding methods discussed later will undoubtedly be of value under certain conditions. Before adapting to military use, many difficult modifications to radio beacons, such as reducing size to render them portable, are necessary.

Reduction in size probably means using shorter wave lengths which with our present knowledge are not suitable for direction finding. Then again there are interference effects artifically produced by other transmitters, or naturally by static, tending to block radio reception. Because of these reasons dependence must be placed largely on methods of avigation self-contained in the airplane.

Theoretically and in a general way, navigation as practiced at sea is adaptable to the air. In practice, however, there is a marked difference between avigation and navigation. This difference arises from conditions which vary greatly between the sea and the air. The first of these which might be mentioned refers to the medium in which each moves. In the case of the ship at sea, ocean currents being accurately charted and of small magnitude and constant over long stretches are corrected for easily. Leeway due to cross-winds is negligible. In the air, on the contrary, the wind varies greatly in direction and velocity with different altitudes and locations and in short periods of time. Its velocity is often relatively large as compared with the speed of the airplane, thereby introducing large angles of side

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drift or in the speed relative to the ground or in both. At sea, the number of knots bears a rather definite relation to the revolutions of the propeller and is easily checked by the log. Likewise because of the minor effect of ocean currents and by the use of accurately compensated magnetic compasses or gyro compasses, direction over the earth's surface is maintained with great accuracy on ships. To correct for the wind effect on the airplane, however, rather precise measurements of drift and ground speed must be made by sighting on some fixed point on the surface of the earth.

While both the ship at sea and the airplane are unstable bases, the shorter period oscillations of the latter render sighting much more difficult and special stabilization for many instruments necessary. This difficulty is especially apparent when making astronomical observations with the sextant. Inasmuch as the natural horizon is rarely visible at the usual flying altitudes, use is made of an artificial horizon, generally a very sensitive bubble. The effect of the aforementioned oscillations on the bubble is quite pronounced.

A further distinction between sea and air navigation arises from the vast difference in their speeds. Reducing observations and plotting position may be done leisurely aboard the relatively slow moving boat. The speed of aircraft requires much faster action, present methods averaging about three minutes between the observation and plotting the position line. Moreover this work must be accomplished usually in a very cramped cockpit. In brief avigation presents a series of special problems not met with in navigation which require not only radical modifications but entirely new instruments and methods.

Although the stars were used in a crude way for obtaining general direction from the most ancient times, the compass provided the first means of sufficient precision to be useful for marine navigation. Even on steel boats, it is possible to adjust the magnetic compass with great precision. It is true, however, that with the advent of the gyro compass on the larger boats the magnetic compass is becoming a secondary standard, so to speak. Unfortunately no gyro compass has been developed for

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aircraft. With the installation and use of the magnetic compass on aircraft arose many old problems in a most aggravated form. The necessity of mounting the compass in line with the pilot's eye, places it in close proximity to steel members of the airplane and to the electric circuits and instruments. The problem of accurately adjusting an aircraft compass is still a serious problem, it often being impossible to reduce errors symmetrically for all headings. In the latter case recent experiments on shielding electric instruments appear promising. Vibrations arising from modern aircraft engines require new developments in the suspension of the compasses.

Due to the speed and range of present day aircraft it becomes difficult when flying certain courses to correct at the proper time and by the right amount for changes in the magnetic declination or the direction of the earth's magnetic meridians. On the flight of Major Coste from Paris to Tsitsibar, Manchuria, for example, there was a change of 22 degrees in the magnetic declination.

The airplane is unique, as a vehicle in that it maneuvers in three dimensions. This property has given rise to a serious problem, viz., that of maintaining straight and level flight when the usual visible references such as the horizon, earth, and sky are obscured. Clouds, fog and snow not only affect actual flight but also landing. Some phases of the fog landing problem will be discussed later in connection with radio. So many important factors are considered in connection with the design of present day airplanes that it has been impossible to make them inherently stable to the extent that they will, of themselves, maintain straight and level flight for long periods. It has also been demonstrated by tests on the ground and in the air, that, minus the usual visual references, the human sense of equilibrium is faulty.

The equilibrium sense of the pilot, made up of a combination of the inner ear and muscle senses, reacts properly when subject to the influence of gravity alone. In flight, however, centrifugal force due to turning and changes in speed caused by the pitching of the airplane introduce false reactions giving the pilot an erroneous idea of the vertical and of straight flight. Under the

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influence of the same accelerating forces the compass becomes undependable. To cope with these conditions associated with "blind" flying, new instruments had to be devised and some of the former standard instruments used in new ways.

The defect of the magnetic compass has been overcome by the addition of an air-spun gyroscope which detects turns by precessing. When the centrifugal forces of turning have been eliminated by use of the gyro, a simple spirit level, pendulum or the equivalent is sufficient for maintaining the wings level laterally. The air-speed indicator operated by the dynamic pressure of the air stream on a pitot tube is adequate for maintaining level flight longitudinally, provided the pitot tube is not blocked by snow or ice.

Some measure of the longitudinal attitude of the airplane may be obtained from the rate of climb indicator, an instrument which measures the vertical rate of change of the pressure of the atmosphere. Both the air speed meter and rate of climb meter must be interpreted in connection with the indications of the engine speed, as shown by the tachometer, in order to gain a correct idea of the longitudinal turn.

Recent improvements in gyroscopes have given use to an instrument called the artificial horizon. On the dial of this instrument a bar, representing the horizon rises or falls and tilts with respect to a small picture of an airplane, giving directly a conception of pitch and bank. This simplified method of conveying needed information to the pilot, represents a distinct advance in "blind" flying instruments. The necessity for the pilot to interpret a large number of pointers on arbitrary scales in order to form a mental image of the attitude of his airplane with reference to the earth, is being eliminated. Lately the gyroscopic turn indicator has been caused to indicate relative motion by rotating a picture of the landscape in the proper direction. The picture presented to the pilot thus becomes more natural. The effect of these developments on both military and commercial aviation will be profound. The greatest air disasters occurring in transport aviation during the past year were caused by bad-weather flying. Then again, even with the

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low prevailing rates of air transportation, the unreliable schedules mitigate against large increases in traffic. The approach of the final solution of the bad-weather problem means dependable schedules and safety, the two requisites required of any means of transportation before the public will patronize generally.

During military operations and under ordinary conditions, well-matched air forces largely neutralize each others' efforts. The air force that can use clouds and fog to the greatest extent for protection and surprise enroute to and from the objective obviously has a tremendous advantage. Practice in bad weather operations probably offers as much opportunity of increasing the tactical efficiency and general effectiveness of military aviation in the near future as will be derived from improvements of the airplane itself.

RADIO NAVIGATION

Since radio by its nature is able to provide the pilot with valuable information relating to facts exterior to his plane, it will play a very important rôle in the future development of commercial and military aviation. From a scientific standpoint the aircraft radio aids are still in their infancy and many pilots are still under the impression that a ship equipped with radio and direction finding apparatus is a reflection on their ability. The weight, the technical complications of the equipment, unreliability under certain conditions and the difficult technique of operating the apparatus are factors which oppose the universal adoption of radio on aircraft today.

Due to the pressing demands for radio, however, rapid progress is being made in overcoming these handicaps. Lighter, simpler and more reliable equipment is under development and great efforts are made by the radio manufacturers toward greater simplicity and ease of operation possible. Until recently for instance the trailing wire antenna was used for the transmission and reception of radio signals from aircraft. The disadvantages of this type of antenna are:

a. Additional job imposed upon the pilot, already busy with numerous other activities, to unreel it after taking off and to reel it in before landing.

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b. Directional effect changing the intensity of received signals when the position of the antenna with respect to the electromagnetic field changes.

c. Greater accumulation of static charges during storms or when flying through clouds.

By increasing the sensitivity of the receivers and decreasing the wave length of the transmitter, it is possible to use antennas stretched between the wing tips or even metal rods of few feet in length mounted vertically above or horizontally below the fuselage. It is obvious that this type of antenna requires no attention on the part of the pilot after installation.

In power equipment great improvements are in sight. The old air-driven generators are rapidly replaced by engine-driven generators which means sensible saving in weight or pay load and performance. A further step will be made by utilizing alternating current generators instead of direct current for plate supply.

The greatest difficulty encountered in the utilization of radio on aircraft is interference from ignition. To overcome this effect the wires are wrapped outside the insulation with closely woven wire braid, known as shielding, which eliminates the radiated energy by grounding to the frame of the airplane. Complete shielding of magnetos, spark plugs and spark-plug leads appears to be the only solution of this problem. Due to feed-back low tension wires must also be shielded. Fairly satisfactory shielding equipment is available. There is no doubt that in the near future all aircraft motors will be provided with built in shielded ignition harness at the factory.

It is very difficult today to make sure statements indicating the trend of the type of radio receivers and transmitters to be used on aircraft for communication purposes. The old equipment using wave lengths ranging from 600 to 1200 meters is heavy and complicated but insures reliable communication between the airplane and ground if the atmospheric conditions are normal. The laws of propagation of these waves are well known and their propagation is almost uniform in all directions.

The modern equipment makes use of shorter waves, using

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fixed antenna simpler apparatus and is considerably lighter. Unfortunately the laws of propagation of the short waves are not very well known and their reflection by the ionized upper layer of the atmosphere renders their utilization for reliable military operations uncertain.

For interplane communication the utilization of ultra short waves of the order of few meters offers splendid possibilities. Since these waves propagate in straight paths without bending, the straight line connecting the two airplanes must be free from all obstacles which would absorb them. The curvature of the earth's surface, therefore, imposes a distinct limitation on the range.

A very valuable use of radio on aircraft is for navigation purposes. Utilizing the directional characteristic of a loop antenna a course can be laid out between two airports and the pilot can follow this course using a very simple receiving equipment. A vertical 6-foot pole antenna, a sensitive receiver and a pair of good ear phones is all that is necessary to follow the course laid out by a directional aural beacon such as installed by the Department of Commerce on the national airways. The pilot knows immediately when he is on the right or left of his course by two distinct signals which interlock into a long dash on the course.

In the near future the aural system will probably be replaced by a visual type in which a simple instrument installed on the dash board indicates whether the airplane is on or off the course. This improvement requires only minor modifications of the transmitter on the ground, the output of the transmitter, which is fed into the two loop antennaes, being modulated to two different frequencies. Two reeds on the instrument board, tuned to these frequencies and which are plugged into the receiver, vibrate equally when the airplane is on the center of the course. Any deviation to either side causes a corresponding increase in the amplitude of vibration of one reed and a decrease in the other.

Another method of radio avigation, known as the homing method, permits the pilot to direct the nose of his airplane towards any transmitting station of known location. A loop antenna with the plane perpendicular to the longitudinal axis of

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the airplane will not receive any signal from the transmitting station when the airplane flies in the direction of that station. If the output current of the radio receiver associated with the loop is rectified and sent into a measuring instrument installed on the dashboard, the pilot navigates so that there is no deflection of the needle.

The further development of this homing method is evolving into an automatic radio compass in which a floating needle points continually towards the transmitting station. In this case the loop is of smaller dimensions and rotates with uniform speed.

Still another method of position finding of an airplane in flight is to install the radio transmitter on the ship. When the pilot wants his position he calls the control station of a network of direction finders located on the ground. Two or three of the ground stations, by rotating loop antennae, read at the same time the angle made by the direction of the airplane with the north direction and communicate by telephone their readings to the control station. The position of the airplane is then readily determined on a map and communicated in less than one minute to the pilot by radio. This system is used at Croyden Aerdrome in England and requires a very efficient ground organization.

The most important contribution of radio science to aircraft navigation will probably be the locating of landing areas in poor visibility and aiding in the safe landing by instruments alone.

A number of solutions have been offered and there is no doubt that in the near future the problem of fog navigation will be entirely solved. Marker radio beacons are already installed along the beacon courses of national airways informing the pilots of their position. As the pilot approaches a beacon station the signals become stronger and stronger. At a distance of several miles it is perfectly possible to send the rectified output of the receiver into a device indicating distance. Now he knows that in vicinity of the radio beacon a landing field is available and watches closely the intersection of the long range beacon with a smaller type beacon called runway localizer. The present type runway localizer affects two vibrating reeds installed on the dashboard of the airplane similar to the visual beacon described

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above except of shorter range. From now on the pilot abandons the long range beacon and follows the runway beacon which guides him towards the center of the field. Along this narrow path a sharp boundary marker indicates when the airplane has crossed the boundary of the field and if at this point the pilot knows his true altitude a safe landing can be negotiated. In the present state of art this altitude can be obtained on a sensitive barometric altimeter corrected so that it will read zero when the wheels touch the ground. This correction can be obtained by radio from the airport authorities a few minutes before landing. Using equipment developed by the Bureau of Standards for the purpose, the foregoing system was used in making simulated fog landings last year under the auspices of the Guggenheim Fund.

Recent development and scientific research, by the Bureau of Standards, indicates that even a gliding path in a beam of ultra-short radio waves can be provided for the pilot when he follows the runway localizer beacon. By merely keeping the deflection of an electric meter constant or, in other words, following a surface on which the strength of the electromagnetic field is constant, the airplane is brought automatically from an altitude of say 2000 feet at 3 miles out, to a landing position 15 feet above the ground in the center of the field. The trend in the development of fog landing aids is to operate the transmitting equipment on the ground keeping the airplane equipment light and simple and compact, using if possible a single radio receiver for all purposes.

There still remains the danger of collision between airplanes flying the same beacon course at the same altitude in opposite directions. The use of ultra-short wave beams radiated from airplane combined with directional receivers will solve this problem also in a very short time. It is expected that with adequate traffic control and well organized airways with frequent intermediate landing fields, airplanes will navigate with safety in any kind of weather.

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THE DIVISION OF AERONAUTICS OF THE LIBRARY OF CONGRESS*

A. F. ZAHM, PH.D.

Chief, Division of Aeronautics, Library of Congress, occupying the Daniel Guggenheim Chair of Aeronautics

The immense expansion of aeronautical activity throughout the world has made desirable in this country a national aeronautic library commensurate with that expansion. The recent efforts of the Library of Congress to meet this desideratum are outlined in the following account.

SCATTERED COLLECTIONS BEFORE 1930

Need for centralized aeronautic collection

Prior to 1929 the Library of Congress had not endeavored to secure an extraordinary collection of aeronautical literature, nor to provide specialists to facilitate the public's use of the limited material on hand. No special fund as yet had been provided for the purchase or service of such material. Books and pamphlets obtained by copyright, exchange or gift of persons and institutions had steadily accumulated; but no collections in bulk had been acquired. No concerted effort had been made to centralize comprehensively at any one national establishment either the ancient or the rapidly-growing current literature of aeronautics, as obviously should some time be done in the interest both of scholars writing histories, treatises or text-books, and of active technical men—laboratory investigators, inventors, designers, engineers, administrators, manufacturers, transporters, pilots, instructors, lawyers, etc.—engaged in the scientific production, operation and regulation of aircraft.

* Received for publication July 25, 1930.

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Random independent collections

Accordingly various governmental branches had assembled independent aeronautic libraries, which entailed duplication of material and effort. Among these were the Smithsonian Institution, the Army, the Navy, the Department of Commerce, the National Advisory Committee for Aeronautics. Some of the departments had several aeronautical collections accumulated more or less at random. Besides these, there were private collections of specialists, or of institutions. Such was the Octave Chanute collection in the John Crerar Library, Chicago; that of the Aeronautical Chamber of Commerce, New York City; that of the National Aeronautic Association, Washington, D. C., etc.

THE GUGGENHEIM GRANT

Initial negotiations

In January, 1929, the Daniel Guggenheim Fund for the Promotion of Aeronautics proffered its good offices toward forming at the Library of Congress an aeronautic collection which eventually might become "The most important aeronautical library in this country, and perhaps even in the world." The quoted words are from a letter to the Librarian by Mr. Harry F. Guggenheim, President of the Fund, expressing his readiness to recommend to its trustees a grant to the Library if it could secure from the other federal agencies having aeronautical libraries whole-hearted coöperation in concentrating there the greatest possible amount of aeronautic library material. Captain Emory S. Land, (C. C.), U. S. N., Vice-President of the Fund, had previously ascertained that some members of these agencies deemed such concentration both feasible and desirable.

Conference of librarians

Pursuant to the suggestion of Mr. Guggenheim and Captain Land, made in their correspondence with Doctor Putnam, he invited to the Library, for a conference with him on February 26th, the following persons:

Lieut. John D. Barker, U. S. A., for the War Department Air Corps.
Dr. W. L. Corbin, for the Smithsonian Institution.

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Mr. Stafford Kernan, for the Department of Commerce.
Mr. John F. Victory, for the National Advisory Committee for Aeronautics.

Doctor Putnam opened the meeting by recounting his previous correspondence with the officers of the Guggenheim Fund. He especially recalled their joint opinion that the Library of Congress ought to have the most general and comprehensive deposit of aeronautical literature augmented in part by voluntary transfers from the government's other aeronautical libraries which, however, should always maintain their confidential files and essential working material. Jointly, too, they had anticipated from the other agencies most friendly coöperation on receiving assurances of such acquistions in the National Library, with its exceptional facilities for servicing them.

Sense of the meeting

The response of the meeting was quite as cordial as had been anticipated. The opinion was unanimous that development of the proposed collection should be at the Library of Congress, and that other aeronautic branches of the government should endeavor to strengthen it, avoid unnecessary duplication, and direct research to it.

Special stress was laid upon the need of expert service not merely to develop the collection but to interpret it and aid serious readers in its effective use. Besides the usual cataloguer, classifier, bibliographer or reference librarian skilled in library mechanics, there should be in charge of the collection a specialist in the subject matter, a man combining advanced scientific and technical training with bibliographical knowledge, one accomplished in aeronautics as a science and familiar with its practice as an art.

Doctor Corbin's report

Doctor Corbin, in his report of the conference to the Secretary of the Smithsonian Institution concluded:

"The conferees were convinced that, if adequate means could be provided by the Guggenheim Fund for carrying out the two projects mentioned, the Fund would thus very materially advance the cause of

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aeronautics in the United States. They will look forward to its decision with the keenest interest. If it is favorable, I shall take pleasure in recommending to you that the Langley Aeronautical Library be transferred from the Smithsonian Institution to the Library of Congress."

The final outcome of the correspondence and discussions above recounted was the communication of a grant of $140,000 to the Library by the Daniel Guggenheim Fund for the Promotion of Aeronautics. Its application is specified in the Librarian's annual report for 1929.

THE CENTRALIZED AERONAUTICAL COLLECTION

Having received from the Guggenheim Fund assurance of a liberal grant, Doctor Putnam, in the spring of 1929, took steps to form an aeronautic division in the Library of Congress and to provide personnel and material for it.

Bulk and piecemeal accessions

The national library was now prompt to procure aeronautic collections in bulk or piecemeal; by purchase, transfer, gift or bequest; to become the centralized depository, in the United States, for the most effective working material and for the most precious treasures—books, pamphlets, manuscripts, prints, engravings, autographs, original drawings, objects of art, etc.—garnered by enthusiasts throughout the world from time immemorial.

Four famous collections

After careful preliminary negotiations in the spring of 1929, and later, the Librarian received from Maggs Brothers, booksellers in London, a letter, dated December 6 offering to send him for inspection four important aeronautical libraries. These are known respectively as: (1) the Tissandier collection; (2) the Hoernes collection; (3) the Silberer collection; (4) the Maggs collection. This combination was regarded as the finest available library of its kind that could be purchased anywhere in the world,

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and was eagerly sought by other agencies. Accordingly it was ordered by the Librarian by cable, and arrived in New York in the *S.S. Aquitania*, January 15, 1930, a consignment of 33 cases weighing gross 3 tons, 3 cwts.

It was a splendid purchase. "Altogether," wrote Maggs in their notice of shipment, "we think you will be delighted to have this magnificient collection, and we are delighted that we are the cause of your getting it, with one lingering tear in each eye that it will leave England forever."

The collection in toto

At the time of this purchase, in April, 1930, the whole aeronautical collection in the Library of Congress numbered as follows:

Aeronautical collection in the Library of Congress, April, 1930

	Volumes and pamphlets
Original Aeronautical Collection in Library of Congress, Apr'l, 1930.	3113
Gaston Tissandier Collection	1800
Hermann Hoernes Collection	783
Victor Silberer Collection	895
Maggs Brothers Collection	621
Samuel Pierpont Langley Collection	2115
	9327

The Tissandier collection

The Tissandier collection is particularly rich in works on the early history of aeronautics, including many sixteenth and seventeenth century books. It contains approximately all the worthwhile aeronautic literature published in France up to 1900. It forms the subject matter of two books by Gaston Tissandier, and has furnished illustrative material to most French authors on the history of aeronautics. It comprises the whole collection of Dupuis-Delcourt, another airship constructor, which was accumulated before 1860 and later purchased by Gaston Tissandier. The complete Tissandier collection is the patient life work of the brothers Gaston and Albert Tissandier (famous balloonists, writers and constructors of an electric dirigible), enriched by additions of Gaston's son Paul Tissandier, "himself aeronaut and avi-

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ator, possessor of the most important library and the most beautiful aeronautic collection of the eighteenth century."

The Silberer collection

The Victor Silberer collection contains several long runs of periodicals and many books which the collector received as owner-editor of two aeronautic periodicals. Besides the modern books, there are several old and rare items, and many scarce pamphlets and reprints. Silberer's own books are naturally included. Born in Vienna in 1846, Silberer became prominent in Austrian civil and military aeronautics, was honorary member of several aero clubs, and made 147 balloon voyages.

The Hoernes collection

The Hermann Hoernes collection comprises the material for writing Hoernes' three-volume handbook of aeronautics, "Buch des Fluges." Like the Silberer collection, it has many periodical sets and numerous reprints and clippings from periodicals. Born in Austria in 1858, Colonel Hoernes, at thirty years of age, was sent by the war ministry to study aeronautics in Germany, France and England. He achieved distinction as a military aeronaut, writer, engineer and inventor. Like Silberer, he was prominent in various aeronautic societies, and was the recipient of many decorations for meritorious service.

The Maggs collection

The Maggs Brothers, London booksellers, had issued in two parts a fine descriptive catalogue of books, engravings and autographs illustrating the evolution of the airship and the airplane; Part I in 1920, Part II in 1923. All of the 621 volumes that remained of the Bibliotheca Aëronautica in 1929, save 197 items duplicated in the collections of Tissandier, Hoernes, Silberer, were bought by the Library of Congress in 1930.

The Langley collection

The Samuel Pierpont Langley collection comprises first the private aeronautical libraries of Langley and of James Means,

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second the accessions added by the Smithsonian Institution through purchase or exchange. It is especially rich in very complete files of important aeronautic periodicals. The whole collection was placed on deposit in the Library of Congress in March, 1930.

GENERAL CHARACTER OF THE NEW COLLECTION

Scope of new collection

As a whole, these five accessions cover the accumulated results of aeronautic research and experiment from the earliest times down through the ages till, after the development of the internal-combustion engine, they finally culminated in the production of practical airships and airplanes of immense commercial and political importance.

Pre-balloon aeronautica

The new collection contains many sixteenth and seventeenth century books on general science having chapters on the possibility of flying. There are two editions of Porta's "Magiae Naturalis," both from the Plantin press. A very precious item is a fine copy of Fauste Veranzio: "Machinae Novae," containing an illustrated description of a parachute (1595). There are also several works by Athanasius Kircher, Gaspar Scott, Caramuel de Lobkowitz, and other early scientists. Of great importance is Giovanni Alfonso Borelli's "De motu animalium," of which there are four separate editions. Equally important is Francesco Lana's "Prodromo all' arte maestra," of which there is a fine copy. A famous and exceedingly scarce book is Joseph Galien's "L'art de naviger dans les airs." Most of the celebrated works of early aeronautical fiction are in the collection, such as Goodwin, Peter Wilkins (Paltock), Cyrano de Bergerac, Restif de la Bretonne, Ben Johnson's Rasselas, etc.

Early balloon literature

The collection contains many of the early books inspired by the invention of balloons. Such are the writings of Faujas de Saint Fond, Robert, Tiberius Cavallo, Rozier, Bourgeois, and many

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others, historical and technical books, as well as poetry and drama. Probably very few of the books published during this period are lacking. There is also a run of the *Journal de Paris*, 1881–1888, where the story of the invention of balloons is told in the form both of news items and of comments.

Now follow a considerable number of pamphlets, containing reports of individual balloon voyages. Noteworthy among these are Blanchard's reports on his various aerial ventures; also the report of Dr. Jeffries, on his famous balloon voyage with Blanchard across the British Channel. The latter pamphlet is very scarce. There are similar reports, by Vincent Lunardi, Garnerin, Zambeccari, and many others.

Free balloons

The literature on free balloons is very well represented. There are books on the operation and construction of balloons, as well as descriptions of voyages; and on ballooning for sport, and exhibition, as well as for scientific and military purposes. The activities during the Siege of Paris in 1870 form an interesting chapter in the history of ballooning. There is in the collection considerable material, both books and clippings, concerning this period. Among the most interesting items may be mentioned the newspapers, printed on tissue paper for lightness, which conveyed the news of Paris, by way of balloon mail, to the rest of the world.

Dirigibles

The problem of dirigibility of balloons occupied the minds of most aeronautically interested men for nearly a century, before real success began to dawn. This subject prompted numerous books, many of which are now very scarce and sought for by collectors. This literature is very well represented in the collection, and comprises the really important works that advanced the art.

There is a very valuable paper by General Meusnier, written in 1784, and an album containing large-size photographs of his original designs and tables of data for an airship with man-driven screw propellers. There are books by the French airship constructors Dupuis de Lome, Henry Giffard, Renard, and Tissan-

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dier; and by the German constructors Haenlein, Gross, Parseval and Zeppelin.

Aviation

From the year after the first balloon ascent there are three books on heavier-than-air craft; one is a study of bird flight, by Huber, the other two contain flying-machine projects, by Gerard and Meerwein. The latter is regarded as the first to suggest approximately the right size of wings to support a man.

Among the books on natural flight are those of Mouillard and of Count d'Esterno. Mouillard's "L'Empire de l'air" is one of the classics of aviation, now rare, and so is "Du vol des oiseaus," by d'Esterno, of which there are two editions. The studies of Professor Marey, Pettigrew, Prechtel, Strasser, and many others are in the collection.

Aerodynamic works

Among the important works on aerodynamics and aviation may be mentioned A. Goupil's "La locomotion aerienne" describing his invention of the modern three-torque system of control; also A du Roy de Bruignac's "Recherches sur la navigation aerienne," 1875, in which is presented analytical proof that a given smooth gliding plane can be supported with less power at high than at low speed. Other valuable aerodynamic works are those of Penaud, Ritter v. Loessl, Buttenstedt, Kress, Ader and Eiffel. There are further the writings of the helicopter enthusiasts, Nadar, De la Landelle and Ponton d'Amecourt.

Miscellaneous

There are numerous books on aeronautical engineering, aircraft construction, motors, hangars; also some volumes on aerial law and on hygiene of aviation. Among works on military aviation are more than a hundred instruction pamphlets, issued confidentially by the different armies during the world war.

History material

On the whole, the collection is very rich in first hand material, the results of original research. In addition, there are historical

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books, works written for popular consumption and text-books. There are also some precious antiquarian items, highly esteemed by collectors; such as the score of beautiful balloon almanacs from the end of the eighteenth century. Among the historical works may be mentioned Bruel: "Histoire Aeronautique," and its continuation by Comte de la Vaulx. These consist chiefly of excellent reproductions of prints and manuscripts, with explanatory text, many are reproduced after originals that are now in this collection.

Manuscripts

The collection of books is supplemented by a very large collection of manuscripts. Among the most precious items are some of the original manuscripts of the Montgolfier brothers, inventors of the hot air balloon; an original letter, dated November 21, 1783, of Benjamin Franklin to Sir Joseph Banks, describing and shrewdly appraising the spectacular first balloon ascension in history, made in a hot-air bag, September 27, 1783, by the Marquis d'Arlande and Pilatre de Rozier; the original autograph manuscript report of the first hydrogen balloon ascent, read by the inventor and pilot himself, Professor J. C. A. Charles, to the Paris Academy of Sciences in 1784. There are also original manuscripts by the early balloonists, notably Garnerin and Blanchard. From recent times there are manuscripts by Air-commodore Maitland.

Most of the men that have been prominent in the history of aeronautics are represented by manuscripts contained in the collection; some by lengthy letters, notebooks, etc.; others at least by an example of their signature. Many of the books also contain autograph dedications from the authors, and many have personal letters inserted.

Prints

A large number of aeronautical prints from a valuable part of the collection. Many of these are of artistic merit, and most of them of historical interest. There are also many original pencil and water color drawings, and many photographs.

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Clippings

Of interest to the historian will be the vast amount of clippings from newspapers and periodicals. These in part have been arranged in scrap books by their previous owners.

CHARACTER OF SERVICE TO BE RENDERED

The Library of Congress is in part a bureau of information, in part an institution for comprehensive and systematic research.

Miscellaneous studies

In the first capacity it answers annually tens of thousands of inquiries addressed to it in manifold ways—by mail, telephone, telegraph or cable, by personal conference or messenger. These answers for the most part are made by citations of printed authorities, bibliographies, publications exhibiting material in the National Library or in other readily accessible places, such as various branches of the Federal Government or various local libraries. The questioner may also consult the Library's material directly. "Any person from any place may examine within its walls any book in its possession, and may do this without introduction or credentials."

Systematic research

In the second capacity the Library of Congress furnishes both material and expert assistance to persons engaged in research apt to advance the boundaries of knowledge. Under the interlibrary loan system, it lends certain books to other libraries for the use of investigators engaged in serious research; thus rendering to scholarship a special service not within the power or duty of such local libraries. "It meets the unusual need with the unusual book." Furthermore, having special endowed "chairs," it may furnish to a few researchers such personal aid as is commonly rendered to advanced students by graduate departments in the universities.

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Preëminent scope of the Library's reference literature

There are, of course, many American institutions equipped to furnish ready information in practically the whole range of aeronautics. Such are the correspondence schools, the Aeronautical Chamber of Commerce, and some of the aeronautic branches of the federal government. But for comprehensive, thoroughgoing, systematic research, requiring the greatest range of reference literature, the National Library is, and naturally should be, preëminent. Its preëminence is due not only to its greater number of aeronautic works—books, pamphlets, periodicals and serials— but to its vast accumulation of allied literature absolutely essential to such research. In theoretical aerodynamics, for example, many of the great masterly fundamental contributions are found scattered in a multiplicity of scientific periodicals, particularly those devoted to mathematics, mechanics and physics, which are not possessed by the above-named institutions, but which stream into the Library of Congress continuously from all quarters of the world, and in some cases have been so streaming for many decades. Only with such facilities can one write a comprehensive treatise or memoir in a highly developed science.

THE ULTIMATE GOAL

But pre-eminence alone is not sufficient. Completeness is the ultimate goal. All the important aeronautic library material extant should be found, unique or duplicate, in the Library of Congress. To that end numerous other libraries, public and private, are closely compared; book stores are searched; trade catalogues studied. Bibliophiles who during many years of life find happiness in accumulating rare material will be glad to know of a national centre where their life's treasured collections can be safely deposited and remain forever intact, rendering greatest service to the greatest number of readers. Whoever contributes to the completeness of the National Library does a national service.

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IRON IN BERMUDA*

W. L. R. EMMET, D.Sc.

Consulting Engineer General Electric Company; Member National Academy of Sciences, etc.

The Island of Bermuda is separated from the continental shelf by five or six hundred miles of deep ocean. It is built of coral rock which can be examined in its many caves and quarries and on all its shores. This rock is made up of coral débris most of which has been deposited as coral sand and has concreted into a soft rock which can be cut with saws, is almost perfectly white and practically free from silicious matter and from iron. An English report gives the analysis of this rock as follows:

	per cent
Water	0.316
Organic substance	3.806
Sand	0.050
Sesquioxide of iron, Alumina	0.520
Lime	52.470
Magnesia	1.686
Potash	0.064
Soda	0.243
Carbonic acid	42.866
Sulphuric acid	0.206
Chlorine	0.020
Phosphoric acid	0.077

The fertile soil of Bermuda which is found in various valleys and pockets is of a deep red color and the same report gives its analysis as follows:

	per cent
Water	6.930
Organic substance	14.910
Silicic acid	0.034
Sand	20.100

* Received for publication, August 14, 1930.

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	per cent
Sesquioxide of iron	28.650
Alumina	22.900
Lime	3.334
Magnesia	0.091
Potash	0.155
Soda	0.055
Carbonic acid	0.767
Sulphuric acid	0.060
Chlorine	0.042
Phosphoric acid	0.620

In several places where the coral rock has been quarried for building purposes, a vein of red material bedded in a practically horizontal plane is revealed. In the places where I examined these beddings they were about a foot thick. Some pieces of this red material which I picked from the surface and which were presumably more or less changed by weathering showed about 50 per cent silicon, 25 per cent alumina and 25 per cent iron oxide.

The question which I consider interesting and significant relates to the source of such deposit of iron, silica and alumina on a remote ocean island built of clean coral from which these substances are almost entirely absent.

In a paper which I originally wrote in 1907, and which in slightly changed form was published in the *Scientific Monthly* on January, 1927, I explain a theory of the earth's upbuilding with which such a phenomenon seems consistent and in connection with which I seek to account for other iron deposits.

My paper assumes for the earth and other planets a history of upbuilding similar to that which I believe to be depicted on the face of the moon.

By this theory the last stages of the earth's upbuilding were punctuated by the plunging into its surface of bodies previously independent which had grown to considerable sizes possibly such as are found in the belt of planetoids.

The laws of probabilities and of astronomical forces would indicate that these arrivals must have been separated by vast periods of time and that in studying the geological history of the earth we are looking at, not an earth which had reached its present size five or six hundred million years ago, but that of a grow-

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ing earth which has been through many changes of condition through the arrivals of large bodies which have plunged into it with long ages of quiescence separating their arrival.

In the paper above mentioned a part of my description of conditions which might follow the entrance of such a large body into the earth reads as follows:

"To portions of the world not directly involved the effects of such an occurrence would be largely climatic. The diurnal period and the position of the poles might be slightly changed; great quantities of vapor and CO_2 gas would presumably be put into the atmosphere, geographical changes might greatly affect ocean currents and other conditions which influence climate. Changes of level would flood or drain portions of continental areas. Quantities of solid matter would presumably be thrown out by the effects of extreme heat near the surface but such effects would be local. From larger planets some matter might be thrown out with sufficient velocity to cause it to escape from the parent body and such actions might account for the comets and meteorites which inhabit our solar system, but which have no definite relation to the general plane of its rotary motion."

"An interesting fact suggestive of this theory of meteorites is that they are composed largely of iron. The rocks of the earth contain large quantities of iron in chemical combination with other materials and it might be expected that very intense heating would drive off quantities of iron vapor. Since such discharges of metallic iron which were scattered on the earth or in its atmosphere would be rapidly corroded and absorbed by water and later deposited in sedimentary beds we might conceive that such conditions could explain large deposits of iron ore in certain places. Such deposits seem to suggest an origin very different from any present day rock disintegrations."

It seems obvious that this red material in Bermuda has fallen upon the island from the atmosphere. The island has undoubtedly been depressed and lifted but this red layer could not be an ocean deposit. If it were it would be like other ocean ooze and not made up so largely of iron, alumina and silica. It is also difficult to imagine that this could be the result of some volcanic eruption of the ordinary type. Volcanoes throw out great quantities of silicious matter in the form of dust but they do not,

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as far as I know, throw out iron except as a constituent of the liquid lava. The silica presumably has been in solution in water under high pressure and is blown out with the steam. The soil produced by the disintegration of lava is often red with iron, but volcanic ash deposits are nearly white.

To drive iron vapor from the earth would require a condition very different and of much higher temperature than anything associated with ordinary volcanic action.

Such a deposit might easily result from such occurrences as I have considered and its existence in such a place gives support to my theory of the earth's history.

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ARMS*

RICHARD D. STEUART

Curator of Arms, Maryland Academy of Sciences Museum.

Self-preservation is the first law of nature, so that almost the first purpose to which the ingenuity of man was devoted was to devise weapons of offense and defense. These were needed to provide man with food, to defend him against the wild beasts and to defend his life and property against his fellow man, scarcely less wild and probably much more bloodthirsty than the beasts.

Man's first weapon undoubtedly was a club. A sharp stone in the head of the club made it more effective. Then the club was sharpened and pointed, and the sword was evolved; first made of wood, then of bronze and finally of iron and steel.

But man's strength was no match for the great prehistoric beasts that roamed the earth, so again he had to put his wits to work. Then he devised the missile weapon. By putting a sharp stone point on a long pole he had a spear or javelin, which he soon learned to throw with considerable accuracy. His next thought was some sort of mechanical device which would propell a missile with greater force and precision than his brute strength, and the sling, hurling a stone, was the result. That this was effective is proved by the Biblical story of David and Goliath.

The next step was the bow and arrow, the origin of which is lost in the mist of antiquity. The bow and arrow were known to most primitive people throughout the world, and it only needed some man with a little more mechanical genius than his fellows to invent the cross-bow, which substituted mechanics for human brawn in propelling the pointed arrow through the air. And the cross-bow was the ancestor of the gun.

The history of weapons of war is really the story of man's progress, and the study of ancient arms and their development

* Received for publication September 20, 1930.

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is a fascinating one to the student of history. More than once a new type of weapon has changed the eistory of a people. Even in our own country, the part played by the rifle in winning the wilderness from the savage and in beating back the trained troops of a foreign power has not been overlooked by historians.

Just when gunpowder was "invented" is a question which no one seems able to answer. Certainly it was known to the ancients in China, who used it mostly for pyrotechnic displays. It was only when more civilized peoples discovered its possibilities that, as the old doggerel says:

> They did most fearful things with it,
> They blew up popes and parliaments,
> And emperors and kings with it.

The first firearms were cannon, and it is certain that they go back to 1313, but it was not until 1375, according to the chroniclers, that hand-cannon, or what we commonly call guns, were first used.

These early hand-cannon were merely pieces of iron pipe, closed at one end and fired with a slow-burning match. Usually it took two men to operate them, one to hold the gun steady on a forked stick thrust into the ground and the other to apply the lighted match.

About 1425 the matchlock, or first practical hand gun operated by one man, was invented. It had a stock-shape so as to be rested against the chest, and a metal lever held a slow-burning fuse which the gunner could pull against the touch-hole, firing the gun. The matchlock was in common use for more than two centuries.

The matchlock was the common arm of the early American colonists. While the wheel-lock, the next step in the development of firearms, had been in existence nearly a century when Jamestown, Plymouth and St. Mary's were founded, yet it is believed there were few, if any, wheel-locks among the first settlers of Virginia, Massachusetts and Maryland.

Dr. Raphael Semmes, in a paper read recently before the Maryland Historical Society, said there was no record of wheel-

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locks among the Calvert pioneers. The explanation is that the wheel-lock was essentially a sporting weapon. It was not practical as a military arm, and the colonists wanted a weapon that was cheap and serviceable.

The flintlock, which was a marked improvement on the wheel-lock, although on the same principle, came into vogue in about the middle of the seventeenth century. By 1690, in the reign of William and Mary, the entire English army was equipped with flintlock muskets, the grandfather of the "Brown Bess" and the great-great-grandfather of the Enfield.

The flintlock military arm held sway for nearly two hundred years and was superseded by the percussion lock, which in this country, had its first real try-out in the Mexican War. The Civil War proved that the breech-loading metallic cartridge weapon was far superior to the percussion lock, although many distinguished generals of the Union Army were opposed to the new-fangled arms.

The repeating military gun also came out while the Civil War was on, as did many other improvements in firearms, the worth of which was not proved until many years after that great conflict. It is rather flattering to our pride to learn that so many devices used in the recent World War originated on this side of the Atlantic in the battle of the States. Ironclads, submarines, observation balloons, torpedo boats, armored railroad cars, hand-grenades, trench-mortars, bomb-proofs and other factors, which played so big a part in the World War were all used by North or South in 1861–65.

The Maryland Academy of Sciences is particularly fortunate in having one of the finest collections of antique firearms and other weapons in this part of the country. It cannot, of course, compare with that in the National Museum, in Washington, but I know of no other public collectionin the East which includes such a wide variety of specimens and so many rare types. The arms collection of the Metropolitan Museum, New York, is composed almost exclusively of arms that antedate the period of firearms.

The nucleus of the Academy collection exhibition, which fills one room of the museum, was the collection of the late Henry

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Wever, of Baltimore and Byrdton, Virginia. Mr. Wever, a gentleman of independent means, spent years in travel and in the acquisition of his very extensive collection. After his death the collection was presented to the Academy by his brother, George D. Wever, of Baltimore. Incidentally, Mr. George D. Wever refused a large sum for the collection, setting a good example to other members of the Academy.

With the Wever collection as the magnet, the Academy has been the recipient of other specimens, singly and in groups, from members and friends of the institution.

The collection embraces about one thousand items and depicts the history of firearms from the crude hand culverin of 1400, which was hardly more than an iron pipe closed at one end and fired from a forked stick thrust in the ground, to the latest magazine guns of the World War.

There are cross-bows—the progenitor of the gun—Japanese matchlocks, wheel-lock arquebuses of the sixteenth century, Oriental snapchaunce and flintlock guns, many of them elaborately decorated and inlaid with mother-of-pearl, semi-precious stones and gold and silver ornamentation by native gunsmiths.

There is a group of flintlock blunderbusses of English and Belgian workmanship. The blunderbuss was a short gun, with bell-shaped muzzle, which was very effective for household and stage coach defense. They were loaded with a handful of slugs and were deadly at close quarters.

In the blunderbuss class is a fine specimen of an old ship's swivel of the seventeenth century. In old sea tales you read of a ship being armed with so many guns and so many swivels. These swivels were large guns and blunderbusses, which were kept in racks below decks until the ship went into action when they were mounted on the ship's rail, where there were sockets for that purpose. There is also a large swivel gun in the collection.

Only one cannon is included in the collection. It is an old Spanish piece of bronze, bearing the royal coat-of-arms and captured in the Philippines in 1898. But there are other and bigger guns than this, and some of them are of local interest. These are the "outlaw" duck guns used in Maryland waters and

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confiscated by our game wardens. A splendid specimen of these illegal weapons used by pot-hunters was presented to the Museum recently by our State game warden. It is nearly 12 feet long,

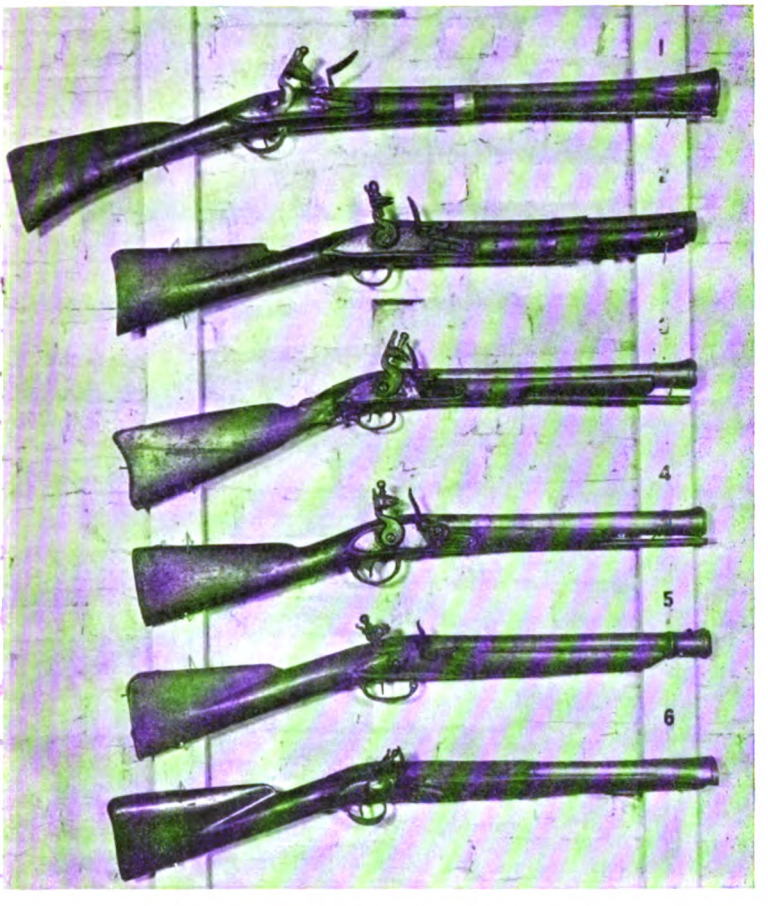

FIG. 1. A HALF DOZEN BLUNDERBUSSES

The blunderbuss was a short gun, with a flaring muzzle, which was loaded with slugs and used for home and coach defense. *1* and *2* are very early types of English blunderbuss; *3*, *4* and *5* are later models, with brass barrels; *6* is a Belgian blunderbuss with elliptical muzzle, which scattered its discharge in a fan-shape mass.

with a $1\frac{1}{2}$ inch bore and fired by a percussion lock. The lockplate is from an old Springfield army musket.

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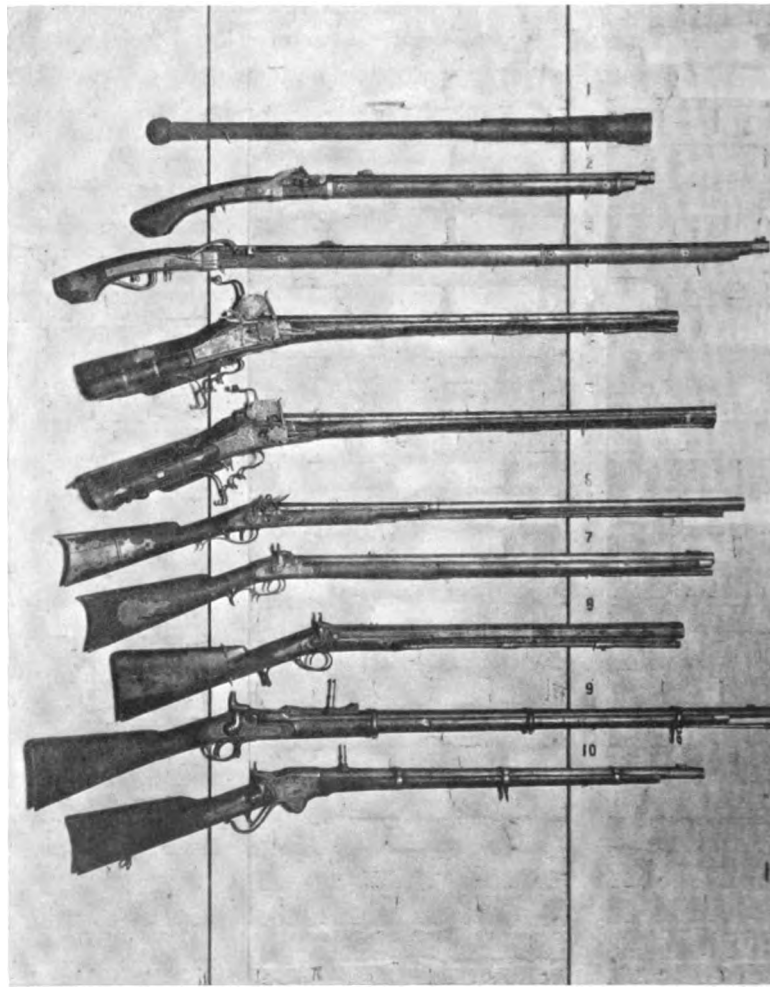

FIG. 2. FOUR CENTURIES OF GUNS

1, German hand culverin, the earliest type of hand firearm; *2* and *3*, Chinese matchlocks; *4* and *5*, Austrian wheel-lock guns; *6*, American flintlock rifle; *7*, American flintlock rifle altered to a percussion lock; *8*, American percussion lock rifle; *9*, American breechloading rifle. *10*, American magazine rifle.

In one corner of the arms room is a little group of guns, which presents the whole story of the development of firearms in a few symbols. There is the handculverin, the first gun; the match-

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lock, the wheel-lock, the flintlock, the flintlock altered to percussion, the percussion, the breechloader and the repeating gun. They cover a period of nearly four centuries.

The collection is particularly rich in Americana. There are specimens of the French, English and Dutch muskets, with which the early settlers of this country fought the Indians. The earliest American military firearm is represented by a musket made in New Jersey for the Continental Congress and so marked.

There is also one of the Charleville muskets, such as Lafayette brought to this country to help arm the Revolutionists. And this arm was used as the model for the first regular army musket made by the United States Government, which was manufactured at Springfield Armory in 1800. It, too, is represented in our arms room. The most typical of all American arms is the flintlock rifle, which proved such a formidable weapon against the British in 1776 and with which our early settlers conquered the wilderness. This had its origin in Pennsylvania, where among the early settlers were many German and Swiss gunmakers. These village gunsmiths made the short, heavy, bigbore rifle of Europe—the kind with which the Hessian riflemen were armed—but they were not popular in this country. What the American pioneer wanted was a long, small calibre rifle, light and easy to handle and load.

So the early Pennsylvania gunsmiths changed their style and evolved the rifle which was known as the Kentucky rifle, although in some parts of the South it was called the Tennessee rifle. No matter what its name, it was the most formidable weapon of its day. What Jackson's Tennessee riflemen did to the British at New Orleans with this arm is a matter of history.

It was this rifle which the United States Government used as the model for our first Government-made military rifle, manufactured at Harpers Ferry soon after 1800. Some of these rifles were in the hands of the regulars at New Orleans, and a fine specimen is in our collection, as are several varieties of the Kentucky rifle.

A logical successor to the Kentucky flintlock rifle was the light, percussion rifle, also made in Pennsylvania, in the Forties, and

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known as Indian rifles and Plains rifles, because they were the chief dependence of the men who crossed the plains to the Far West in the days of the California gold rush. The Museum has several fine Plains rifles. The name Indian rifle was applied to the gun, because hundreds of them were made by Government order for presentation to the Indians—a unique case of the Government providing the Redskins with arms to fight our own soldiers and citizens.

We have said that the Civil War gave us the breechloading military rifle, but, as a matter of fact, the United States Government had a breechloading rifle nearly half a century before that conflict. This was the Hall rifle,[1] the invention of Colonel John H. Hall in 1811, and manufactured at the Harpers Ferry Armory. The Hall rifle, one of which is in our collection, is a flintlock and was the first breechloading military arm of any nation. It was used in the Seminole and Mexican Wars, but was not a practical arm. At the outbreak of the Civil War many Hall rifles and carbines were altered to percussion and issued to the troops, but were soon discarded for more practical weapons. Another arm of considerable historic significance in the collection is a musket made in Columbia, S. C., in 1852, when the question of secession was first agitated. The Legislature of South Carolina ordered the Palmetto Armory to manufacture muskets, rifles and pistols and they were turned out in large quantities.

Coming down to the Civil War period, the Wever collection includes most of the shoulder arms used at that time. These include specimens of the contract rifled muskets, which were made in large numbers by Northern firms, the Colt revolving rifles, made by the same firm which manufactured the famous Colt revolvers, and examples of the old flintlock muskets which were converted to percussion lock and issued to the troops in the early days of the war when improved firearms were scarce. At that

[1] Ingenious gunsmiths had devised breechloading guns and pistols even as early as the seventeenth century. A breechloading rifle, invented by Colonel Ferguson was used by British troops at the battle of King's Mountain in 1780. However, the Hall was the first military rifle approved and manufactured by any Government for its army.

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time thousands of English Enfield rifles were imported by both the North and South and proved to be an excellent infantry arm. Several types of this gun are shown.

When the Confederates under Stonewall Jackson captured Harpers Ferry in 1861, the small guard of Federal troops at the arsenal fired the buildings and retreated into Maryland. The flames were extinguished by citizens, and Jackson's men were enabled to seize thousands of partly completed muskets and rifles, as well as all the arms-making machinery. When it is

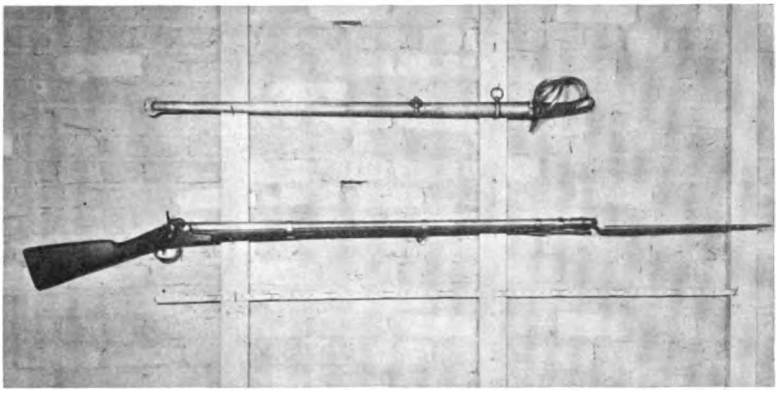

FIG. 3. ARMS OF TWO LOST CAUSES

(*Above*) A St. Étienne sabre of 1811, such as used by Napoleon's cuirassiers at the Battle of Waterloo. (*Below*) A musket made at the Palmetto Armory, Columbia, South Carolina, by order of the South Carolina Legislature of 1852 when the first secession agitation took place.

remembered that there was no arms-making machinery in the South, except small plants at Feyetteville, New Orleans, and two or three other places, the importance of this capture is realized.

The Harpers Ferry machinery was divided, that for making the rifled musket being sent to the Virginia Armory at Richmond, and that for making the short rifle being sent to Fayetteville, N. C. At both places this machinery did good service for the South, turning out excellent infantry arms. The Museum is fortunate in having a specimen of both these products—the Fayetteville and Richmond rifles.

The north side of the arms room is devoted to sporting weapons,

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and in this group are many varieties of the long rifle, previously described as the Kentucky or Tennessee rifle; numerous flintlock and percussion fowling pieces and shotguns, including one fowling piece of fine workmanship, made for a left-handed man.

In this section, too, are the Scheutzenfest rifles, which are of special interest to Baltimore, because the shooting festival was

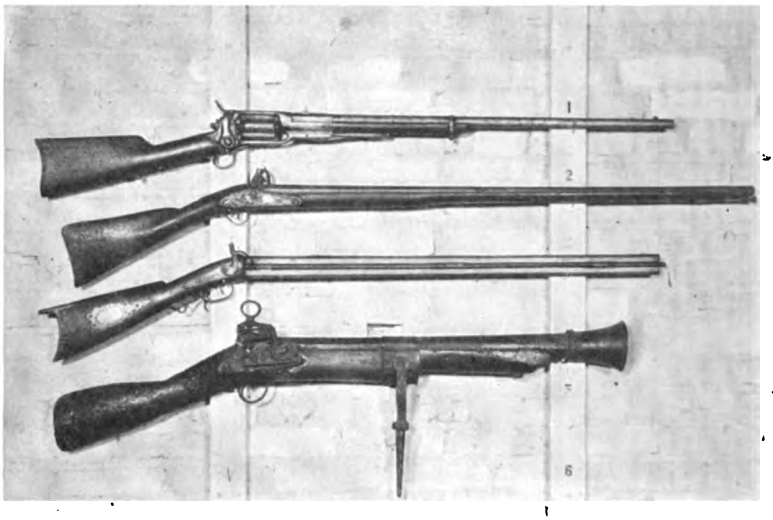

FIG. 4. FOUR RARE TYPES

(*Top*) A Colt revolving military rifle invented and made by Col. Samuel Colt, inventor of the famous Colt revolver. Many of these rifles were used in the Civil War. (*Next*) A flintlock fowling-piece made for a left-handed man. The lock is on the left side of the gun which is designed to be fired from the left shoulder. (*Next*) An American double-barrel rifle, the barrels being superimposed. (*Bottom*) An old ship's swivel of the early eighteenth century. Loaded with slugs and nails and mounted on the rail of a ship, it could do fearful execution at close range.

the favorite outdoor sport of our early German citizens. At one time Baltimore had two Scheutzen Parks, one out Gay Street and the other at what is now Carroll Park.

There are target and game rifles, with the hammer under the barrel to avoid interference with the sight; rifles with two barrels superimposed instead of the usual side-by-side, and rifles with hammers on the side, known in their day as "mule-ear" rifles.

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The collection of hand firearms, pistols and revolvers, while not so large and extensive as that of shoulder arms, is scarcely less interesting. There are types of European and early American flintlock and percussion pistols, both military and non-military, and revolvers, American and foreign, in almost infinite variety.

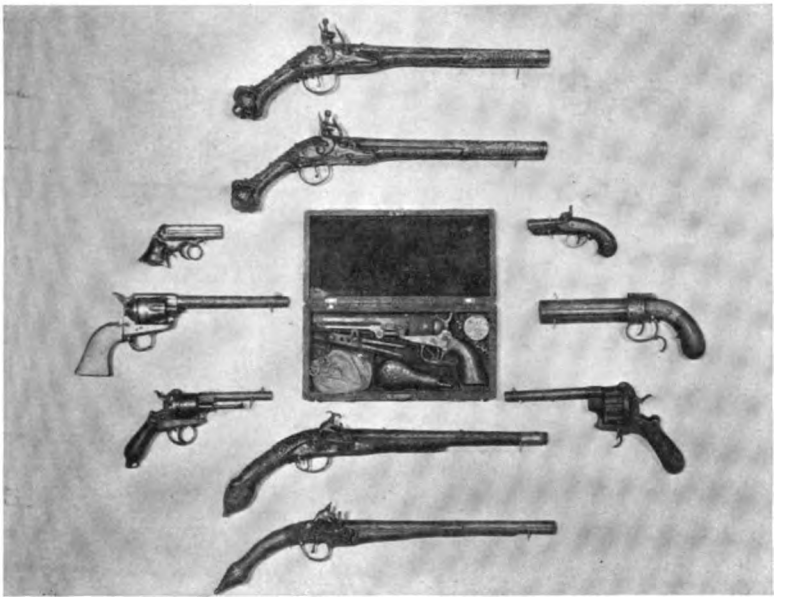

FIG. 5. A GROUP OF RARE HAND FIREARMS

(*Above*) A pair of Oriental flintlock pistols of silver, heavily chased and studded with semi-precious stones. (*Below*) Two ancient Moorish pistols with Spanish miguelet locks. (*Center*) A Colt revolver of 1860 in mahogany case with all accessories. (*Right side*) Top, a small derringer similar to the one with which Lincoln was shot; next, a pepperbox, the pocket weapon of the Forty-Niners; bottom, a French pin-fire revolver. (*Left side*) Top, an American pocket pistol with four barrels; next, the Frontier Colt, or Forty-Five (referring to the calibre), the weapon which played a big part in making the Wild West a fit place in which to live; bottom, a French pin-fire revolver of a type brought to this country at the outbreak of the Civil War, when improved arms were scarce.

Worthy of special mention is a pair of ancient Chinese hand-cannon bearing the coat-of-arms of a family of distinction and a pair of magnificent chased silver Oriental pistols studded with semi-precious stones.

Conspicuous in the revolver group is that masterpiece of the

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famous Colonel Colt, known as the Frontier Colt, a six-shooter of 45 calibre, which was the favorite arm of the Western cowboy, scout and Indian fighter. The Frontier Colt probably was the biggest mechanical factor in the winning of the West. It carried the law into the Wild and Woolly West and at one time was worth its weight in gold dust.

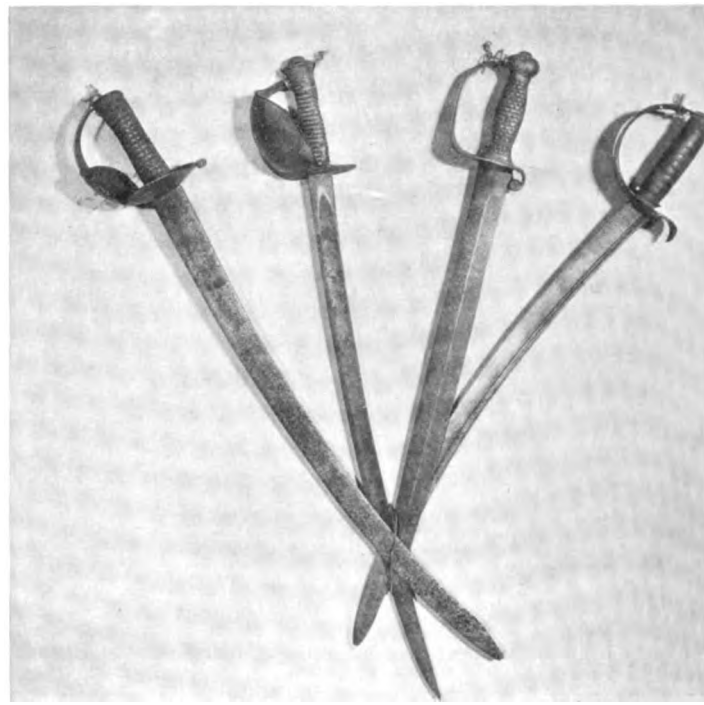

FIG. 6. OUR FIGHTING TARS—IN FOUR CHAPTERS
Cutlasses of the United States Navy. On the extreme left is the cutlass of the Revolutionary War. On the extreme right that of the War of 1812. Second from the right is the cutlass of the Mexican War. Second from the left is the cutlass of the Civil War, which is used in the navy to this day.

The swords and other edged weapons form an interesting part of the collection. There are specimens of all the swords used in the United States Army from the Revolutionary War to the present day and one interesting group shows the four types of navy cutlasses carried by our tars in the Revolution, the War of

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1812, the Mexican War and the Civil War. The cutlass of the Civil War, by the way, is the same used in our navy today. Apparently, it cannot be improved upon.

Among the foreign swords, of which there are very many, is one deserving special note. It is the long, straight, double-edged sabre such as used by Napoleon's cuirassiers at Waterloo and it bears the name of the famous arsenal at St. Etienne and the date 1811, so it is reasonably sure that it was used in Napoleon's last battle.

Many of the Oriental swords and daggers are elaborately decorated and show the wonderful handicraft of the native armorers of Malay, Burmah, South Africa, Persia and other places where the art of the sword-maker was brought to a high state of perfection.

A complete suit of ancient Japanese armour, East Indian shields, tulwars and battle-axes, a pair of Gothic halberds, an ancient battle mace and a fine specimen of the old German flambeau, or wavy-blade sword, are among the other things that attract attention in the collection.

While the group of United States military arms is nearly complete, it lacks two modern types which are needed to finish the collection. They are the United States Army Springfield of 1903 and the Springfield-Enfield rifle, model of 1917, such as was issued to most of our troops in the World War. Perhaps some friend or member of the Academy will supply these wants. The World War is represented by rifles and carbines of the German, French, Belgian and Austrian armies. America should be represented.

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CORRESPONDENCE

British Embassy, Washington
Sept. 29th, 1930.

DEAR COLONEL OWENS,

On learning from Sir John Broderick and Mr. Dew of your call at the Embassy on July 31st, I duly forwarded to the Secretary of State for Foreign Affairs the certificate which you brought with you, nominating the Prime Minister to be an Honorary Member of the Maryland Academy of Sciences, and warmly recommended its acceptance by Mr. MacDonald.

I am happy to inform you that Mr. MacDonald has accepted the nomination by an autograph letter which I have today forwarded to the President of the Academy by registered post and of which I enclose a copy herewith.

Believe me, dear Colonel Owens,
Yours very truly,
(Signed) R. C. LINDSAY.

Colonel R. B. Owens, D.S.O., D.Sc., F.R.S.C.
Maryland Academy of Sciences,
2724 North Charles Street,
Baltimore, Maryland.

British Embassy, Washington
September 29th, 1930.

SIR,

It gives me great pleasure to transmit to you herewith, in accordance with instructions which I have received from His Majesty's Principal Secretary of State for Foreign Affairs, an autograph letter from the Prime Minister of Great Britain accepting his nomination as an Honorary Member of the Maryland Academy of Sciences.

Yours very truly,
(Signed) R. C. LINDSAY.

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The President,
Maryland Academy of Sciences,
2724 North Charles Street,
Baltimore, Maryland.

10, Downing Street, Whitehall
8 September 1930

DEAR MR. PRESIDENT

I have today received the Certificate whereby the Maryland Academy of Sciences does me the great honour of nominating me an honorary member. I am deeply sensible of the high distinction which you have thus conferred upon me and I thank you for it with both pleasure and pride. The Certificate itself, so generous in the terms in which the Academy has seen fit to set forth the reasons for nominating me will always remain amongst my valued possessions.

Believe me to be
Yours very sincerely
(Signed) J. RAMSAY MACDONALD.

THE EARLIEST RECORDED ROCK ANALYSIS

TO THE EDITOR,
Dear Sir:

It may be of interest to call attention to what is, so far I know, the earliest quantitative analysis of a rock, or the earliest example of a molecular weight determination, dating back over nineteen hundred years. This is an observation of Marcus Vitruvius Pollio, who wrote his treatise on architecture most probably in the time of Augustus, before 14 A.D. I quote from Morgan's translation, 1914, Book II, Chap. V, page 46.

In his section on Lime, Vitruvius explains "the reason why lime makes a solid structure on being combined with water and sand," and the necessity for "burning" it. After pointing out that unburnt limestone mixed with sand will not solidify or hold together, he says: "But if the stone is first thrown into the kiln, it loses its former property of solidity by exposure to the

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great heat of the fire, and so with its strength burnt out and exhausted it is left with its pores open and empty. Hence, the moisture and air in the body of the stone being burned out and set free, and only a residuum of heat being left lying in it, if the stone is then immersed in water, the moisture, before the water can feel the influence of the fire, makes its way into the open pores; then the stone begins to get hot, and finally, after it cools off, the heat is rejected from the body of the lime.

"Consequently, limestone when taken out of the kiln cannot be as heavy as when it was thrown in, but on being weighed, though its bulk remains the same as before, it is found to have lost about a third of its weight owing to the boiling out of the water. Therefore, its pores being thus opened and its texture rendered loose, it mixes readily with sand, and hence the two materials cohere as they dry, unite with the rubble, and make a solid structure."

It will be noted that, in spite of the crude methods of the time, Vitruvius arrived at a very fair approximation to the truth. Calcium carbonate loses 44 per cent of its weight (as CO_2) on complete ignition, and the lower figure of 33 per cent may be accounted for either by the heating in the kiln not being sufficiently high or prolonged to drive off all the CO_2, or because the limestone that Vitruvius used was impure. Nevertheless, this would appear to be the first analysis of a rock on record, and Vitruvius may fairly be said to have anticipated Joseph Black's famous investigation of magnesia alba (magnesium carbonate) by about seven hundred and fifty years.

HENRY S. WASHINGTON.

October 17, 1930.

MR. HERBERT A. WAGNER, *President,*
Maryland Academy of Sciences,
2724 North Charles Street,
Baltimore, Maryland.

Dear Mr. Wagner:

The lathe used at the Johns Hopkins University in the work of Professor Henry A. Rowland is of historical

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scientific interest and value. On it were made mechanisms used in the notable scientific work of Professor Rowland by his well-known mechanician Schneider, and the apparatus was of a high order of precision, besides which the lathe was a center of time spent and attention given by Professor Rowland. He was accustomed to sit on a high chair and rest his feet on the tool-box of the lathe, which shows the worn condition, and I have been told by Doctor Whitehead that many of the interviews with students were thus held.

The lathe was in the shop which occupied the old residence at the Southeast corner of Eutaw Street and Druid Hill Avenue, and was installed about fifty years ago, about two years after the Johns Hopkins University was established. On it three screws were cut and finished, free from errors, for use in diffraction grating ruling machines, the original one being built by Schneider and still at the University in charge of Doctor Wood. The lathe was used, as above, until the death of both of these men in 1901, after which it was operated by Mr. Charles Childs, the present mechanician, until the University moved to Homewood, when I acquired it.

An added feature is a manuscript in Professor Rowland's handwriting, showing the gear ratios from 4 to 100, itemising the threads, studs, and screws.

In order to ensure that this tool may be preserved in tangible evidence of contributions to science by Professor Rowland and by the Johns Hopkins University in Baltimore and the State of Maryland, I take pleasure in presenting this lathe and its equipment to the Maryland Academy of Sciences, which may also put it to practical use in its scientific work.

Lathe Inventory

The lathe, 10 inch swing, 39 inch bed, 56 inches length overall, 4½ inch chuck with two sets of jaws and two keys, reversing screw-cutting carriage, centering slide, and tail stock. Counter-shaft. Gear-cutting attachment with four setting wheels. Twenty gears. Six face-plates from 10 inches to 3 inches. Three slide rests and one holder. Two tail chucks on arbors and one key.

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Twelve inch by one inch milling arbor, and two inside tool arbors. Eight cutting tools, eight centers, and sundries.

With these come, a high-speed lathe with three inch chuck and two buffing heads.

Delivered this date.

Sincerely,

DOUGLASS BURNETT.

STATE OF MARYLAND

CONSERVATION DEPARTMENT

GAME DIVISION

Baltimore, Maryland

October 9th, 1930.

R. B. OWENS, ESQ., D.S.O., D.Sc.,
Executive Officer,
Maryland Academy of Sciences,
Baltimore, Maryland.

Dear Colonel Owens:

I understand that Messrs. Clinton Ruark and W. T. Ruark of Hoopers Island delivered to the Academy this morning the Outlaw Gun and Skiff confiscated by this Department on February 25th on the shore of South Marshes, Somerset County, Maryland.

Mr. W. T. Ruark is mate on the power boat "Canvasback" which is one of the patrol boats used by this Department in the enforcement of the Wild Fowl Laws of this State.

You will find the gun mounts perfectly on the skiff. The gun is a triple barrelled gun, hammer on left instead of right side, with rope attached to top of hammer for the purpose of pulling it back; also a rope attached to the trigger for firing. You will note the gun is very crudely made, the three barrels being held together with iron braces about 12 inches from the end of the barrels.

I am sure this crude equipment which was

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used by one of the pot hunters of Maryland will attract attention and be interesting to the visitors to your wonderful Academy.

Yours respectfully,

(Signed) E. LEE LECOMPTE,
State Game Warden.

ACADEMY NOTES

From *The London Times*,
Saturday, September 13, 1930.

"The Maryland Academy of Sciences, founded in 1797 and the oldest body of its kind in the United States, has conferred upon the Prime Minister, Mr. MacDonald, honory membership of the academy in recognition of his services in the cause of peace."

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THE SOCIETY OF ASSOCIATED SCIENCES OF THE MARYLAND ACADEMY OF SCIENCES

An organization meeting of the above Society was held at the Hall of the Academy on the evening of Wednesday, May 21; Mr. Herbert A. Wagner, President of the Academy, in the Chair.

Mr. Wagner stated that he was deeply interested in medical research and hoped those equally interested would make full use of the facilities of the Academy for this purpose. He further said that he felt there were certain problems relating to the functioning of cells under different conditions or environment, which needed to be attacked by the strongest group of medical men physiologists, biologists, chemists and bio-chemists, botanists, physicists and bio-physicists, that could be gotten together anywhere, and was happy to announce to the membership of the Academy that such a group had been formed.

The names of the officers and members of the group referred to by Mr. Wagner are as follows:

PRESIDENT

Dr. W. H. Howell

SECRETARY

Dr. J. C. W. Frazer

MEMBERS

Dr. Donald H. Andrews, Associate Professor of Chemistry, Johns Hopkins University.

Dr. Charles Austrian, Associate Professor of Clinical Medicine, Johns Hopkins University.

Dr. William S. Baer, Clinical Professor of Orthopedic Surgery, Johns Hopkins University.

Dr. Frederick H. Baetjer, Professor of Clinical Roentgenology, Johns Hopkins University.

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Dr. Walter Baetjer, Associate in Clinical Medicine, Johns Hopkins University.
Dr. Lewellys F. Barker, Professor Emeritus of Medicine, Johns Hopkins University.
Dr. Joseph Colt Bloodgood, Clinical Professor of Surgery, Johns Hopkins University.
Dr. Thomas R. Boggs, Associate Professor of Clinical Medicine, Johns Hopkins University.
Dr. Curtis F. Burnam, Lecturer in Radium Therapy, Johns Hopkins University.
Dr. Janet Clark, Associate Professor Physiology, School of Hygiene and Public Health, Johns Hopkins University.
Dr. William Mansfield Clark, De Lamar Professor of Physiological Chemistry, Johns Hopkins University.
Dr. Thomas S. Cullen, Professor of Clinical Gynecology, Johns Hopkins University.
Dr. J. M. T. Finney, Professor of Clinical Surgery, Johns Hopkins University.
Dr. J. C. W. Frazer, B. N. Baker Professor of Chemistry, Johns Hopkins University.
Dr. Eugene M. K. Geiling, Associate Professor of Pharmacology, Johns Hopkins University.
Dr. Louis Hamburger, Associate in Clinical Medicine, Johns Hopkins University.
Dr. W. H. Howell, Director and Professor of Physiology, School of Hygiene and Public Health, Johns Hopkins University.
Dr. Herbert Spencer Jennings, Director of the Zoological Laboratory, Johns Hopkins University.
Dr. Sebastian Karrer, Director Physical Laboratory, Consolidated Gas Electric Light and Power Company.
Dr. Dean Lewis, Professor of Surgery, Johns Hopkins University.
Dr. Warren H. Lewis, Professor of Physiological Anatomy, Johns Hopkins University.
Dr. E. V. McCollum, Professor of Bio-Chemistry, School of Hygiene and Public Health, Johns Hopkins University.
Dr. Sydney R. Miller, Associate in Clinical Medicine, Johns Hopkins University.

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Dr. R. B. Owens, Director of Research, Maryland Academy of Sciences.
Dr. Walter A. Patrick, Professor of Chemistry, Johns Hopkins University.
Dr. William A. Perlzweig, Associate in Medicine, Johns Hopkins University.
Dr. A. H. Pfund, Professor of Physics, Johns Hopkins University.
Dr. Maurice Pincoffs, Professor of Medicine, University of Maryland.
Dr. E. Emmet Reid, Professor of Chemistry, Johns Hopkins University.
Dr. F. C. Rice, Associate Professor of Chemistry, Johns Hopkins University.
Dr. Arnold R. Rich, Associate Professor of Pathology, Johns Hopkins University.
Dr. Arthur Shipley, Lecturer in Clinical Surgery, Johns Hopkins University.
Dr. William S. Thayer, Professor Emeritus of Medicine, Johns Hopkins University.
Dr. George Walker, Director of Cancer Research Laboratory, Maryland Academy of Sciences.
Dr. Robert W. Wood, Professor of Experimental Physics, Johns Hopkins University.

A short paper was read by Dr. Sebastian Karrer, Director of Research of the Consolidated Gas Electric Light and Power Company, describing a newly-perfected thermocouple for the measurement of internal temperatures of animals.

Others who spoke at the Meeting were: Dr. J. C. W. Frazer, Dr. E. V. McCollum, Dr. Maurice Pincoffs, Dr. R. B. Owens, and Dr. George Walker.

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THE LIBRARY

New Book Shelf

Aeronautics: I. Heavier-Than-Air Craft. Compiled by M. J. B. Davy. His British Majesty's Stationery Office.

Aeronautics: III. The Propulsion of Aircraft. Compiled by M. J. B. Davy and G. Tilghman Richards. His British Majesty's Stationery Office.

Agricultural Implements and Machinery. A. J. Spencer, M.I.Mech.E., and J. B. Passmore, M.Sc. (University of Reading). His British Majesty's Stationery Office.

Air Defence. Major-General E. B. Ashmore. Longmans, Green & Co.

Alternating Current Rectification. L. B. W. Jolley, M.A.(Cantab.), M.I.E.E., Association American I.E.E., Member, Research Staff of the General Electric Company, Ltd. John Wiley & Sons, Inc.

American Food and Game Fishes. David Starr Jordan, Ph.D., President of Leland Stanford Junior University, and Barton W. Evermann, Ph.D., Ichthyologist of the United States Fish Commission. Doubleday, Page & Co.

Ants. William Morton Wheeler, Ph.D., Professor of Economic Entomology, Harvard University, Honorary Curator of Social Insects, American Museum of Natural History. Columbia University Press.

Astronomy and Cosmogony. Sir Jas. H. Jeans, M.A., D.Sc., LL.D., F.R.S., Secretary of the Royal Society, and Research Associate of Mount Wilson Observatory. University Press.

Astronomy, Introduction to. Forest Ray Moulton, Ph.D., Professor in Astronomy in the University of Chicago, Research Association in the Carnegie Institute of Washington. Macmillan Co.

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Astronomy: I. The Solar System. Harry Norris Russell, Ph.D., D.Sc., Raymond Smith Dugan, Ph.D., and John Quincy Stewart, Ph.D., of the Princeton University Observatory. Ginn & Co.

Astronomy: II. Astrophysics and Stellar Astronomy. Russell, Dugan and Stewart. Ginn & Co.

Atom, The Structure of the. E. N. DaC. Andrade, Ph.D. (Heidelberg), D.Sc. (London), Quain Professor of Physics in the University of London, and Fellow of University College, London. Harcourt Brace & Co.

Atoms, Molecules and Quanta. A. E. Ruark, Ph.D., Physicist, Mellon Institute of Industrial Research; Lecturer in Physics at the University of Pittsburgh, and H. C. Urey, Ph.D., Associate Professor of Chemistry at Columbia University. McGraw-Hill Book Co. Inc.

Bacteriophage and Its Behavior. F. D'Herelle, M.D., Directeur du Service Bacteriologique du Conseil Sanitaire, Maritime et Quarantenaire d'Egypte. Williams & Wilkins Co.

Biochemistry, Outlines of. Ross Aiken Gortner, Professor of Agricultural Biochemistry in the University of Minnesota and Chief of the Division of Agricultural Biochemistry, University of Minnesota, and the Minnesota Agricultural Experiment Station. John Wiley & Sons, Inc.

Bird Homes. A. Radclyffe Dugmore. Doubleday & McClure Co.

Bird Neighbors. Neltje Blanchan. Doubleday & McClure Co.

British Birds. F. B. Kirkman, B.A. (Oxen), Editor and part author of the *British Bird Book*, etc., and F. C. R. Jourdain, M.A. (Oxon), author of *Eggs of European Birds*, part author of the *Practical Handbook of British Birds*, *British Bird Book*, etc. T. C. and E. C. Jack, Ltd.

Catalogue, Science Museum, South Kensington. Compiled by E. A. Forward, A.R.C.A., M.I.Mech.E. His British Majesty's Stationery Office.

Land Transport:

Vol. I, Road Transport. Compiled by E. A. Forward, A.R.C.S., M.I.Mech.E. His British Majesty's Stationery Office.

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Vol. II, Mechanical Road Vehicles. Compiled by E. A. Forward, A.R.C.S., M.I.Mech.E. His British Majesty's Stationery Office.

Vol. IV, Railway Construction and Working. Compiled by E. A. Forward, A.R.C.S., M.I.Mech.E. His British Majesty's Stationery Office.

Railway Centenary Exhibition Supplement. Compiled by E. A. Forward, A.R.C.S., M.I.Mech.E. His British Majesty's Stationery Office.

Water Transport:

Vol. III, Steam Ships of War. Compiled by G. L. Overton, A.R.C.S. His British Majesty's Stationery Office.

Vol. VI, Marine Engines, and Vol. VII, Marine Boilers. Compiled by G. L. Overton, A.R.C.S. His British Majesty's Stationery Office.

Electrical Communication:

Vol. I, Line Telegraphy and Telephony. Compiled by R. P. G. Denman, M.A., A.M.I.E.E. His British Majesty's Stationery Office.

Vol. II, Wireless Telegraphy and Telephony. Compiled by R. P. G. Denman, M.A., A.M.I.E.E. His British Majesty's Stationery Office.

Electrical Engineering. Compiled by F. St. A. Hartley, A.C.G.I. His British Majesty's Stationery Office.

Catalogue, Science Museum, South Kensington. His British Majesty's Stationery Office.

Chemistry. Compiled by A. Barclay, A.R.C.S., A.I.C. His British Majesty's Stationery Office.

Metallurgy. Compiled by A. J. Spencer, M.I.Mech.E. His British Majesty's Stationery Office.

Mathematics. Compiled by D. Baxandall, A.R.C.S., F.R.A.S. His Majesty's Stationery Office.

Mechanical Engineering. His British Majesty's Stationery Office.

Miners' Lighting Appliances. Compiled by A. J. Spencer, M.I.Mech.E. His British Majesty's Stationery Office.

Mining and Ore Dressing. His British Majesty's Stationery Office.

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Textile Machinery. His British Majesty's Stationery Office.

Machine Tools. His British Majesty's Stationery Office.

Meteorology. His British Majesty's Stationery Office.

Stationary Engines. Compiled by H. W. Dickinson, M.I.Mech.E. His British Majesty's Stationery Office.

Charts and Maps. His British Majesty's Stationery Office.

Chemical Theory, The Foundations of. R. M. Caven. D.Sc. (London), F.I.C., Professor of Inorganic and Analytical Chemistry in the Royal Technical College of Glasgow. Blackie & Son, Ltd.

Chemistry, An Elementary Study of. Wm. McPherson and Wm. Edwards Henderson, Professors of Chemistry, Ohio State University. Ginn & Co.

Chemistry in Daily Life. S. Glasstone, D.Sc., Ph.D., F.I.C., Lecturer in Chemistry at the University of Sheffield. Methuen & Co., Ltd.

Chemistry in Modern Life. S. A. Arrhenius, Ph.D., M.D., D.Sc., LL.D., Director of the Nobel Institute, the Swedish Academy of Sciences, President of the Swedish American Foundation (Sverige Amerika Stiftelson). D. Van Nostrand Co., Ind.

Chemistry, Outlines of Theoretical. F. H. Getman, Ph.D., (Johns Hopkins) formerly Associate Professor of Chemistry in Bryn Mawr College. John Wiley & Sons, Inc.

Commutator Motor. E. J. Teago, D.Sc., M.I.E.E., Robert Rankin Professor of Electrical Machinery in the University of Liverpool, Chartered Electrical Engineer. Methuen & Co., Ltd.

Congressional Directory. United States Government Printing Office, Washington.

Dictionary, Cassels New French. Funk & Wagnalls Co.

Dictionary, Cassels New German. Funk & Wagnalls Co.

Dictionary, The Concise Oxford. The Clarendon Press.

Dictionary, James Grassi Italian and English. The Macmillan Company.

Dictionary, Appleton's New Spanish. D. Appleton & Co.

Early Medicine in Maryland. Thomas S. Cullen.

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Electric Rectifiers and Valves. Prof. Dr.-Ing. A. Guntherschulz of the Physikalisch-Technische Reichsanstalt. John Wiley & Sons, Inc.

Electromagnetic Field. Max Mason, of the Rockefeller Foundation, and Warren Weaver, of the University of Wisconsin. University of Chicago Press.

Engineering Index. The American Society of Mechanical Engineers.

Engineering Students, Tables and Units for. C. A. Walker, A.M.I.M.E., M.I.Mar.E., and W. B. Ibbetson, B.Sc., A.M.I.E.E., M.I.Mar.E. Spon & Chamberlain.

Entomology (*A General Textbook of Entomology*). A. D. Imms, D.Sc., F.R.S. Methuen & Co., Ltd.

Essays of a Biologist. Julian Huxley, Professor of Zoology, in the University of London, (Kings College). Chatto & Windus.

Handbook of Chemistry and Physics. Chas. D. Hodgman, M.S., Associate Professor of Physics at Case School of Applied Science, and N. A. Lange, Ph.D., Assistant Professor of Organic Chemistry at Case School of Applied Science. Chemical Rubber Publishing Co.

Hand-List of Short Titles of Current Periodicals in the Science Library (4th Edition). Edited by S. C. Bradford, D.Sc. His British Majesty's Stationery Office.

4th Edition Supplement. Edited by S. C. Bradford, D.Sc. His British Majesty's Stationery Office.

Immunity in Natural Infectious Disease. F. D'Herelle, M.D., Director of the Laboratory of the International Sanitary Council at Alexandria, Egypt. Williams & Wilkins Co.

Industrial Chemistry (*Handbook*). Compiled by A. Barclay, A.R.C.S., A.I.C. His British Majesty's Stationery Office.

Insect Book. Leland O. Howard, Ph.D., Chief of the Division of Entomology, United States Department of Agriculture. Doubleday, Page & Co.

Internal Secretions of the Sex Glands. Alexander Lipschutz, M.D., Professor of Physiology in Dorpat University (Estonia), formerly Privatdocent of Physiology in Berne University, Switzerland. Williams & Wilkins Co.

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Interpretation of Radium. Frederick Soddy, M.A., F.R.S., Dr. Lee's Professor of Inorganic and Physical Chemistry, University of Oxford. John Murray.

Life of the White Ant. Maurice Maeterlinck. Dodd, Mead & Co.

Life of the Bee. Maurice Maeterlinck. Blue Ribbon Books.

Magnetism. Edmund C. Stoner, Ph.D., Reader in Physics at the University of Leeds, Research Fellow of Emmanuel College, Cambridge. Methuen & Co., Ltd.

Maryland Geological Survey, Baltimore County. Johns Hopkins Press.

Matter and Energy. Frederick Soddy, M.A., F.R.S., Lecturer in Physical Chemistry and Radioactivity, University of Glasgow. Henry Holt & Co.

Mechanics and Physics (With a Chapter on Chemistry). A. H. MacKenzie, M.A., B.Sc., A.R.C.Sc. and A. Forster, B.Sc. Macmillan & Co. Ltd.

Medical Dictionary, American Illustrated. W. A. N. Dorland, A.M., M.D., F.A.C.S., Lieutenant-Colonel, M.R.C., United States Army; Member of the Committee of Nomenclature and Classification of Diseases of the American Medical Association; Editor of *American Pocket Medical Dictionary.* W. B. Saunders Co.

Natures Garden (Wild Flowers). Neltje Blanchan. Doubleday, Page & Co.

Nature of the Physical World. A. S. Eddington, M.A., LL.D., D.Sc., F.R.S. Plumian Professor of Astronomy in the University of Cambridge. The Macmillan Co.

Optics, Studies in. A. A. Michaelson, Ph.D., Department of Physics, University of Chicago. The University of Chicago Press.

Physics, Modern. H. A. Wilson, M.Sc., M.A., D.Sc., F.R.S., Professor of Physics, Rice Institute, Houston, Texas; formerly Fellow of Trinity College, Cambridge. Blackie & Son, Ltd.

Physics, Problems of Modern. H. A. Lorentz, Professor in the University of Leiden. Ginn & Co.

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Practical Physics. Robert Andrews Millikan, Ph.D., Sc.D., Director of the Norman Bridge Laboratory of Physics, Pasadena, Calif., and H. G. Gale, Ph.D., Professor of Physics in the University of Chicago. Ginn & Co.

Reptile Book. Raymond Lee Ditmars, Curator of Reptiles in the New York Zoological Park. Doubleday, Page & Co.

Sound, A Textbook of. A. B. Wood, D.Sc., F.Inst.P., Senior Scientific Officer, Admiralty Research Laboratory, Teddington, Middlesex; Member, of Council of the Physical Society of London; late Oliver Lodge Fellow and Lecturer in Physics, Liverpool University. G. Bell & Sons, Ltd.

Telescope. Louis Bell, Ph.D., Consulting Engineer; Fellow, American Academy of Arts and Sciences; Past-President, the Illuminating Engineering Society; Member, American Astronomical Society. McGraw-Hill Book Co., Inc.

Ultraviolet Light and Vitamin D in Nutrition. Katherine Blunt, President of Connecticut College; formerly Chairman of the Department of Home Economics, the University of Chicago, and Ruth Cowan, instructor in Home Economics, the University of Chicago. University Press of Chicago.

Universe Around Us. Sir Jas. Jeans, M.A., D.Sc., LL.D., F.R.S. The Macmillan Co.

Universe of Stars. Based on radio talks from the Harvard Observatory. Observatory, Cambridge, Mass.

Watt Centenary Exhibition, Catalogue of. His British Majesty's Stationery Office.

Watt, James, The Garret Workshop of. H. W. Dickinson, M.I.Mech.E. His British Majesty's Stationery Office.

Wave Mechanics, An Introduction to the Study of. Louis De-Broglie, Docteur-es-Sciences, Professor in the Henri Poincere Institute, Paris. Methuen & Co., Ltd.

X-rays. B. L. Worsnop, B.Sc., Ph.D., Lecturer in Physics, Kings College, London. Methuen & Co., Ltd.

X-ray Crystallography. R. W. James, M.A., B.Sc., Senior Lecturer in Physics, in the University of Manchester. Methuen & Co., Ltd.

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SCIENTIFIC PERIODICALS

Being Regularly Received by the Academy

GENERAL SCIENCE

American Association for the Advancement of Science, Proceedings. Washington, D. C.

American Journal of Science. New Haven, Connecticut.

Archives des Sciences Physiques et Naturelles. Institut de Physique de L'Universite de Geneva, Geneva, Switzerland.

Bulletin de la Section Scientifique. Academie Roumaine, Bucarest, Roumania.

Bulletin Academie des Sciences de l'Union des Republiques Sovietiques Socialistes. Leningrad, U. S. S. R.

Canadian Journal of Research. National Research Council, Ottawa, Canada.

Chicago Academy of Sciences, Program of Activities. Chicago, Illinois.

Comptes-rendus des Travaux. Laboratoire Carlsberg, Copenhagen, Denmark.

Far Eastern University, Publications. Vladivostock, Siberia, U. S. S. R.

London, Edinburgh and Dublin Philosophical Magazine and Journal of Science. London, England.

Memoirs of the College of Science. Kyoto Imperial University, Kyoto, Japan.

Nature. Macmillan Co. Ltd., London, England.

New York Academy of Sciences, Annals. New York City.

Oberlin College Laboratory Bulletin.

Ohio Journal of Science. Columbus, Ohio.

Oklahoma Academy of Sciences, Publications. Norman, Oklahoma.

Bulletin Sciences Mathematiques and Bulletin Science Naturelles; Comptes Rendus des Seances de la Classe des Sciences Mathematiques et Naturelles. Polska Akademja, Krakow, Poland.

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Science. The Science Press, New York.
Science News Letter. Science Service Inc., Washington, D. C.
Scientia. Nicola Zanichelli, Bologna.
Scientific American. New York City.
State College of Washington, Research Studies. Pullman, Washington.
University of California, Publications. Berkeley, Califonia.
University of Neuchatel, Publications. Neuchatel, Suisse, Switzerland.
University of Uppsala, Bulletins. Uppsala, Sweden.
Virginia Academy of Science, Proceedings. Richmond, Virginia.

ASTRONOMY

Allegheny Observatory, University of Pittsburgh. Publications. Pittsburgh, Pennsylvania.
British Astronomical Association, Journal. Metchim & Son, London, England.
Harvard College Observatory, Annals of the Astronomical Observatory of Harvard College; Annual Report of the Director, Bulletins and Circulars. Cambridge, Mass.
Russian Amateur Society for the Study of the Universe, Astronomical Bulletin. Mirovedenie.
Washburn Observatory, University of Wisconsin Publications. Madison, Wisconsin.

PHYSICS

Annalen der Physik. Johann Ambrosius Barth, Leipzig, Germany.
Annales de Physique. Masson et Cie, Paris, France.
Institut de Geophysique et de Meteorologie de l'Universite de Lwow. Poland.
Physical Laboratory of the University of Leiden, Communications. Leiden, Holland.
Physical Society of London, Proceedings. Cambridge, England.
Russian Physical-Chemical Society of Leningrad, Journal. Leningrad, U. S. S. R.
Science Abstracts, Physics. Institution of Electrical Engineers, London, England.

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CHEMISTRY

Chemical Society of Japan, Bulletin. Imperial University, Tokyo, Japan.

Chemical Abstracts. American Chemical Society, Columbus, Ohio.

The Chemical Age. London, England.

The Chemist Analyst. J. T. Baker Co., Phillipsburg, N. J.

GEOLOGY AND PALEONTOLOGY

Geological Survey of Canada, Publications. Ottawa, Canada.

Japanese Journal of Geology and Geography. Department of Education, Tokyo, Japan.

Nationale Museum. Bloemfontein, South Africa.

The American Mineralogist. Princeton University, Princeton, New Jersey.

BIOLOGY AND NATURAL HISTORY

Archivos de la Sociedad de Biologia de Montevideo. Montevideo, Uruguay.

Academy of Natural Sciences, Philadelphia, Proceedings. Philadelphia, Pennsylvania.

American Midland Naturalist. University of Notre Dame, Notre Dame, Indiana.

British Museum of Natural History, Publications. London, England.

Cleveland Museum of Natural History, Annual Report and Bulletins. Cleveland Ohio.

Latvijas Biologijas Biedriba, Journal. Riga, Latvia.

Louisiana State Museum, Biennial Report. New Orleans, Louisiana.

Museo Nacional de Historia Natural. Buenos Aires, Argentinia.

New York State Museum, Bulletin and Handbooks. Albany, New York.

Puget Sound Biological Station, Publications. University of Washington, Seattle, Washington.

Royal Society of London, Proceedings. London, England.

Science Museum, Publications. London, England.

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Sociedad Colombiana de Ciencias Naturales, Revista. Republica de Colomba, Bogota.

Turtox News. General Biological Suppy House, Chicago, Illinois.

BOTANY

Acta Botanica Bohemica, Praha VI. Czechoslovakia.

Boyce Thompson Institute for Plant Research, Contributions and Professional Papers. Yonkers, New York.

Brooklyn Botanic Garden, Contributions, Leaflets and Records. Brooklyn, New York.

Butler University Botanical Studies. Indianapolis, Indiana.

ZOOLOGY

Bird-Lore. Appleton and Company, New York.

Brooklyn Entomological Society, Bulletin. Lancaster, Pennsylvania.

Massachusetts Audubon Society, Bulletin. Boston, Massachusetts.

Museu Zoologico da Universidade de Coimbra, Memorias e estudos. Portugal.

Societe des Amis des Sciences Naturelles, d'Anthropologie et d'Ethnographie, Memoires de la Section Zoologique. Moscow.

The Oologist. R. M. Barnes, Albion, New York.

Zoological Society of London, Reports of the Council and Auditors. Waterlow & Sons Ltd. London, England.

PHYSIOLOGY AND ANATOMY

Archives Neerlandaises de Physiologie de l'Homme et des Animaus. Haarlem, Holland.

Archives of Physical Therapy, X-Ray Radium. Chicago, Illinois.

Instituto de Anatomia. Arquivo de Anatomia e Anthropologia, Lisbon, Portugal.

MEDICINE

American Pharmaceutical Association, Journal. Baltimore, Maryland.

Annals of Tropical Medicine and Parasitology. Liverpool School of Tropical Medicine, Liverpool, England.

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Dental Cosmos. S. S. White Dental Mfg. Co., Philadelphia, Pennsylvania.

TECHNOLOGY, ENGINEERING, INDUSTRIAL CHEMISTRY, ETC.

Bell System Technical Journal. American Telephone and Telegraph Company, New York City.

Canadian Chemistry and Metallurgy. Toronto, Canada.

Canadian Mining and Metallurgical Bulletin. Montreal, Canada.

Carnegie Institute of Technology, Bulletin. Pittsburgh, Pennsylvania.

Franklin Institute, Journal. Philadelphia, Pennsylvania.

International Mediterranean Research Association, Publications. Rome, Italy.

Lamp Development of the General Electric Company, Abstract Bulletin. Cleveland, Ohio.

Mechanical Engineering. Engineering Societies Library, New York City.

Mellon Institute of Industrial Research, Bulletin. Pittsburgh, Pennsylvania.

Renssalaer Polytechnic Institute, Engineering and Science Series. Troy, New York.

Science Abstracts, Electrical Engineering. The Institution of Electrical Engineers, London, England.

The Electrician, London, England.

The Engineering Journal, Montreal, Canada.

MATHEMATICS

American Methematical Monthly. Mathematical Society of America, Lancaster, Pennsylvania.

Annals of Mathematics. Princeton, New Jersey.

Arkiv for Matermatik. Royal Swedish Academy of Sciences, Stockholm, Sweden.

GOVERNMENT PUBLICATIONS

United States—Department of Agriculture. Circulars, Department Bulletins, Farmers' Bulletins, Journal of Agricultural

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Research, Leaflets, Miscellaneous publications and Technical Bulletins.

United States—Bureau of Standards. Bulletins Vol. 1 to 14 complete, and 16 to 22 complete. Journal of Research.

United States—Bureau of American Ethnology. Bulletin.

United States—National Museum. Annual Report, Contributions from the National Berharium and Proceedings.

United States—Naval Observatory. Annual Report, Washington, D. C.

United States—Chemical Warfare. Edgewood Arsenal, Maryland.

United States—War Department. Air Corps News Letters, Air Corps Information Circular. Signal Corps Bulletin.

Smithsonian Institution. Annual Report.

Canada—Department of Agriculture. Report. Ottawa.

Ceylon—Department of Agriculture Publications.

Madras Fisheries Department—India. Administration Report.

Maryland State Department of Forestry. Publications.

Fish and Game Division of California. California State Fisheries Laboratory, Sacramento, California.

MISCELLANEOUS

American Philatelist. American Philatelic Society, Federalsburg, Maryland.

Associazione Internazionale per gli Studi Mediterranei, Bolletino. Rome, Italy.

De L'Union des Scoietes Savantes Polonaises de Leopol. Pologne, Poland.

Dove Marine Laboratory Report. Cullercoats, Northumberland, England.

Geographical Review. American Geographical Society, New York.

Instituto Espanol de Oceanografia, Notas Resumenas. Madrid, Spain.

Maryland Historical Magazine. Maryland Historical Society, Baltimore, Maryland.

Memoria Correspondiente. Madrid, Spain.

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Metropolitan Library, Peking, Annual Report. Peking, China.
National Geographic. Washington, D. C.
National Research Council. Washington, D. C.
National Research Council of Japan. Tokyo, Japan.
Pan-Pacific Union and Pan-Pacific Youth, Bulletin. Honolulu.
Royal Society of Canada, Transactions and Proceedings. Ottawa, Canada.
Tromso Museum, Publications. Tromso, Norway.

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RECENT GIFTS TO THE ACADEMY

From The Consolidated Gas Electric Light & Power Company of Baltimore: 200 Magnets, coils, and parts of meters. 8 Electrical energy meters. 100 Pounds of transformer iron. 3 Transformers.

From the General Electric Company, Schenectady: Thompson voltmeter. 2 Hot wire voltmeters. 2 Hot wire ammeters. Magnets. Instrument coils.

From the Hartford Electric Company: 1 Colored drawing of mercury steam generator.

From a Friend of the Academy: Centrifugal blower. Lens grinding and polishing machine. Standard inductance coils. 4 Horse-power, 110-volt, 32-ampere, 1600-revolution shunt motor. Storage battery jars. Grindstone. Large copper tank. Large marble slab. 3 Slate switch boards. 1 3-phase, 440-volt, automatic starting switch. 2 Potential rheostats. 2 Variable inductances, 4 coils. 1 4-foot precision lathe, with equipment. 1 Single phase, 1000-cycle, alternating current generator. 1 Permanent magnet generator. 1 Set small storage batteries. Infra-red and ultra-violet signaling apparatus. Variable voltage transformer. Variable standard inductances. 6 100-ampere, 500-volt switches. 3 Starting rheostats. 2 Resistances boxes. 1 Variable inductance. 4 Ammeter shunts. 12 Single pole, double pole, triple pole, single and double throw-switches. Small motor generator set. 2 Small D.C. motors. 4 Galvanometers. Standard gas flow meter. 4 Wavemeters. Small wind driver generator. 1 set of primary batteries. 6 D.C. Voltmeters and ammeters. Mercury arc rectifier.

From E. Lee LeCompte, Esq., State Game Warden: Triple barrelled pot hunters' gun, mounted in skiff.

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From Talbott Denmead, Esq., of Bureau of Biological Survey, United States Department of Agriculture: Large pot hunters' swivel gun, 12 feet in length, bore $1\frac{3}{4}$ inches.

From Miss Emma J. Dresel: Collection of medals.

From Douglass Burnett, Esq.: The Rowland lathe.

From Dr. J. Carlton Wolf: Colored map of Panama Canal.

From Hon. Roberto Garcea: Photographs and maps of Mexico.

From Guido Schroedl: Knife made in France and used by French native troops in Algiers.

From Walter F. Hobelmann: Steel-tipped Indian arrow, 2 bayonets and an interesting group of sea shells, coral, etc.

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LECTURES

Second Half 1929–1930 Season

The Equipment and Performance of the Present Day Military Aeroplane. January 8, 1930. By Major-General James E. Fechet, D.A.S., Chief Air Corps, U. S. A.

In this lecture, the power plant, methods and devices for indicating position and elevation, speed and direction indicators, were described, also means of communicating with the ground and other planes; military photography; the use of meteorological data in flying; schemes for aiding the pilot in landing at night or in a fog; altitude and endurance tests; special equipment for long distance flights over difficult country; and attack and defense problems; were explained. The lecture was illustrated.

The Structure of the Air and Aviation. February 12, 1930. By William J. Humphreys, C.E., Ph.D., Professor of Meterological Physics, Weather Bureau, Washington, D. C.

This lecture stressed those structural parts of the atmosphere that are of especial importance to aviation, whether as aids or as obstacles, and particularly the surface turbulence; the change of wind direction and velocity with height; conditions in the region of the cold front or squall line; interplay between wind strata; and; looking to the future, the certain use of the trades and counter trades, and the possible use of even the stratosphere. The lecture was illustrated.

The Struggle between Insect and Man for the World's Food Supply. March 12, 1930. By L. O. Howard, LL.D., Ph.D., D.Sc., M.D., Chief of Bureau of Entomology, U. S. Department of Agriculture, Washington.

In this lecture, the striking fact was brought out that insects are collectively the most powerful enemies and rivals of human-

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ity, and it was stated that in the entomologist and the results of his work, lie our hopes for the future comfort, happiness and prosperity, and even the very existence of mankind. The lecture was illustrated.

Precious Stones: Their Past, Present and Future. April 9, 1930. By Dr. GEORGE F. KUNZ.

In this lecture, Dr. Kunz first spoke of the pearl, the first-known of all gems. He then showed on the screen a greater number of precious and semi-precious stones, many of great historical interest. He also described mining methods and processes of refining and polishing.

Architectural Acoustics. May 14, 1930. By Dr. PAUL R. HEYL.

In this lecture, Dr. Heyl stated that the science of Architectural Acoustics, although over thirty years old, was little known to architects before the recent development of sound pictures brought it forcibly to their attention. It was pointed out that the principles involved are comparatively simple, and that it has been demonstrated that the acoustic character of an auditorium can be predetermined before construction.

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ELECTIONS TO MEMBERSHIP

RESIDENT MEMBERS

Wm. T. Biedler, Esq., The Consolidated Gas Electric Light and Power Company, Lexington Building, Baltimore, Maryland.

Miss Edna A. Brown, Friends School, Homeland, Baltimore, Maryland.

Douglass Burnett, Esq., The Consolidated Gas Electric Light and Power Company, Lexington Building, Baltimore, Maryland.

Miss Katherine E. Clarke, Friends School, Park Avenue and Laurens Street, Baltimore, Maryland.

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NECROLOGY

Howard Bryant, September 18, 1930.
E. J. Silkman, September 26, 1930.

OBITUARY

EDWARD JENNINGS SILKMAN

Edward Jennings Silkman was born November 17, 1859, at Scranton. He was educated in the public schools of Scranton, later moving to New Jersey, where he studied law and was admitted to the practice of law at the New Jersey Bar. In November, 1884, Mr. Silkman came to Baltimore as Secretary to John K. Cowen, General Counsel of the Baltimore and Ohio Railroad Company. His work with Mr. Cowen in the reporting of the latter's speeches in court and on the political platform gave Mr. Silkman the reputation of being the ablest reporter of his day in the State of Maryland. In 1895 Mr. Silkman assumed the management of the Chief Clerk's office in the Law Department of the Baltimore and Ohio and this work occupied his attention until the time of his death on September 26, 1930, caused by a complication of diseases. Mr. Silkman is survived by his widow, Mary H. Silkman, three sons, Major Edwin F. Silkman, U. S. A., Retired, Arthur T. Silkman, and Captain John M. Silkman, U. S. A., and one daughter, Mrs. James Chandlee, of Charleston, West Virginia.

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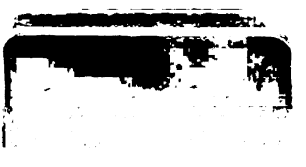

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